With the Author's Compliments

NOTES ON RAILWAYS.

BY

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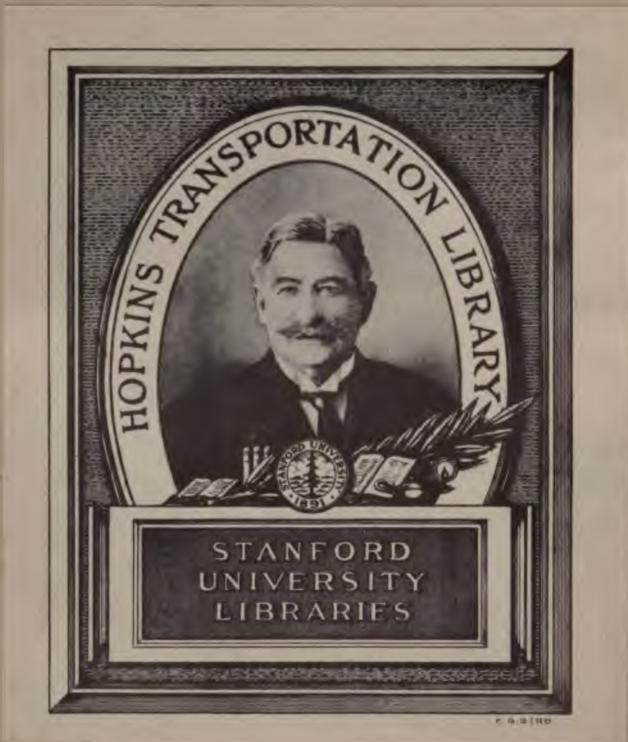
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INTRODUCTORY NOTICE.

The internal economy and external policy of railways, forming a very important portion of the administration of a country, demands a great deal of consideration. The details are so multifarious, and in many cases the action so intricate and difficult to trace, that it seems almost impossible to get at the root of the whole motive power and its effect.

It is not intended it should be understood that the present essay professes to do more than note down the points to which the author has directed considerable attention in an endeavour to throw some light on the subject, and it is hoped that nothing in the style of rendering the notes, which will no doubt be recognized as sufficiently imperfect, will be taken as indicating a wish for the conclusions or arguments to be accepted. No one will be more pleased than the author to receive assistance in arriving at the actual true state of the case whatever it may be, and he would make it his apology for rushing into print that if the various questions which have been now brought up in a definite form are found to have tended hereafter to elicit opinions from his many hard-working and more experienced brother oarsmen in the same boat, confirmatory or the reverse of the results arrived at, one and all may perhaps be more benefited than by each one paddling his own canoe.

It is hardly possible in a small space to enlarge on all the *pros* and *cons* in every case; the salient points have alone been brought forward, and yet they occupy many articles. It will

readily be seen that all that has been said is but a small portion of the matter requiring investigation.

Alluding generally to the subject-matter of the following pages, it may be remarked, that it is quite impossible to deal with the question of the various conditions of the traffic on any particular line. These form a study complete in themselves, and occupy the sole attention of excellent and hard-working officers who may in turn enlighten us in much special knowledge gained in the departments they conduct.

But the general economical working and the administration, though depending on the active intelligence and cordial co-operation of all departments, is still occasionally dependent to some extent on the exercise of principles, the consideration of which does not necessarily fall within the sphere of any one of the departments.

Such principles when applied are apt to be the means of introducing reforms, or alterations, beneficial or otherwise to the undertakings, according to the accuracy of the knowledge of them which may have been attained, and sometimes many questions which must vitally affect the efficiency and economy of the undertakings have the principles which should be the guide, veiled in considerable obscurity.

That 'there is nothing like experience' is no doubt a true and trite saying, and that the results of experience are found to be eminently satisfactory, chiefly to those who having been put to none of the expense necessary to obtain it, are in a position to reap the solid advantages, is equally likely to be true.

It cannot be expected, however, that practice can invariably go without theory to indicate the probable shortest route to the desired goal, and in most of the concerns of life there are recognized principles or theories that are kept well in view for general guidance not to be departed from without cause justly shown.

Railway theories and practice have occupied much time of many able men on various occasions, but it does not appear that there is on record anything tending to determine in more than a very partial way, the actual amount of all the forces making up the machinery of a complete railway required to do any fixed quantity of work.

It has been the object of the enquiries represented by the following notes, to endeavour to ascertain what the amount of these forces is, and the proportion they bear to one another, for if accurately determined, this knowledge must tend to much light being thrown on our general railway policy.

It may be observed that the accounts which should be the *soul of the working*, have hitherto been framed in such a way that though possibly they are suitable for the record of commercial transactions, they can afford scarcely any indication to the Engineer of the wants and requirements of the parts of lines in order to form a harmonious whole.

The talent and skill that has been brought to bear by the Civil Engineers in railway construction, has had to proceed alone and unaided by the experience of past expenditure, and it speaks volumes to their credit to find that they have brought railway construction to such a perfection of harmony and proportion as they have. But when we proceed to compare the working with the result of their labors, and find that all our investigations tend to show the same harmony and proportion in all the parts, as exist in the construction of the lines, we cannot but feel that the experience and scientific research which have established the principles on which the lines have been constructed, have had for their true basis the correct appreciation of the forces to be exerted in the most economical way.

There can be only one maximum effect for every machine, and with a proportion of parts ensuring this, it is quite certain that a deviation in any one of them can produce no greater effect.

In comparing machines, some common standard of their capacity of work must be referred to. The maximum capacity of work will be that giving least amount of force for the greatest effect, and is what is signified by an economical maximum, and this being a point common to all machines can be adopted with least confusion.

In referring to the proportions of railways therefore, it will always be understood that *a straight line on the level in full work* is meant. This common standard being defined it will afterwards be possible to compare the accounts of lines that are not straight, in full work, or on the level, and make many investigations useful to guide us in the administration which at first may appear hopelessly complicated.

The most tangible measure of the forces we are usually called on to put into action is the money cost. The accounts therefore must in themselves contain the exact measure of the force stored up,* and used,† in every part of the machinery of a complete railway: if we only are careful over the classification of the charges, we should be able to measure the components.

These require to be arranged together in classes according to the mode of incidence of the charges, and the *variable* on which they depend has to be clearly recognised in all the items of the accounts for this purpose.

It seems quite astonishing to think that such charges should be lumped together so as to be inseparable, as the following,—

Driving charges............ }
Fuel, oil, water, grease... } for engines,

the two classes being dependent for the actual amount on such different circumstances. Rails and other renewals are quite indistinguishable in the accounts, though the work done is only

* In the Capital Account.

† In the Revenue Account.

gaugeable by the wear of the rails for any given weights and speeds. Stores for trains and stations are all mixed up together. Telegraph, police, and other outside departments, instead of being classed as station establishments, are included in general accounts. Repairs of buildings are not shown with reference to the departments concerned. Lumps of maintenance by contract or interchange of traffic appear, to introduce uncertainty into the proportions of classes, &c. &c.

A great step has been made lately in the classification of Indian accounts, which with slight extension would enable all the items varying with different circumstances to be selected and classed; these will be sufficiently recognised in the course of the following pages, and it will be as well now to proceed to the details of the subject.

In all such investigations one enquiry leads to another, thus drawing us insensibly to the root and motive of the whole operation in its widest application, which root, not seldom, may have its location in a different sphere of investigation to that in which the enquiry originated.

In this instance, railway administration and its effect on the country at large affords great scope for the political economists to dilate upon, and is somewhat beyond the pale of the Engineer's enquiry; yet no one can feel satisfied to leave or approach a subject without at least a glance at the horizon bounding the narrow sphere of his own immediate operations in the great work of the busy world.

Accordingly the essay commences with a brief reference to what seem to be the leading principles involved in the question of railway administration, for it to be of most use to the *country at large, and for every one of the population to be equally benefited.*

The *working expenses* are then taken up, and the influence of the various conditions under which they are incurred investigated.

The capital cost proportions are next considered, and the relative cost of lines of different sizes.

The wear of engines, vehicles, and rails, the composition and nature of the rates charged, are in turn referred to, and a comparison of the 5′ 6″ and 3′ 3″ gauges as regards capability of work investigated. Short notices of branch railways and break of gauge are added, and the whole brought to a conclusion by reference to comparisons of working of English and Indian railways, and some minor matters.

NOTES ON RAILWAYS.

GENERAL CONSIDERATIONS.

1. McCulloch in his Principles of Political Economy, shows that the extension of cultivation is of the utmost importance in a country in progress towards civilization. He shows also that the power of capital and low interest in England as regards the production of piece-goods, places that country above any fear of being driven out of the market by any establishment of spinning machinery in other countries. He also shows that the high rate of wages and low rate of profit in England has the effect of giving a great advantage in commerce to her in those things which are produced by durable capital, while the countries where wages and living are low are at a greater advantage in supplying for export those things in which hand labour is chiefly employed, such as agricultural produce, &c.

Reference to principles of Political Economy.

2. Here in India, where the wages of the labourer are small and his wants few, we are in a position to grow corn and cotton to any extent for export if we can only increase the area of good lands under cultivation. What is wanted therefore is the greatest stimulus to production, and this may be given by *adequate protection* and security to property, by *low taxation,* extension of irrigation over good lands, *cheap carriage,* and, in order to balance cotton and other exports, we must induce a taste for superfluities, which will possibly follow the spread of education.

Requirements of India to stimulate production and trade.

3. The expenditure of capital on railways and irrigation in countries where wages are low and the soil the chief producer, acts differently to that expended on manufactures. As shown before, manufactures will find

Difference in Capital expended in Railways and Irrigation to that spent in Manufactures.

their place in highly civilized countries having much capital and a dense population, because wages perform only a portion of the work. Railways and irrigation, by extending the area of profitable cultivation, stimulate production and population; the owners of lands already in cultivation find their land more valuable and returning a higher rent, which rent will most possibly be expended in the purchase of superfluities, to the eminent advantage of the markets of more advanced nations. In the operations of Government, the land will return more rent in proportion to the extent of cultivation and increase in population. Other taxation may be reduced, and profits of labour increased accordingly.

Excess Earnings on Railway and Irrigation.

4. Money earned on capital expended by Government on railways in excess of the current rate of interest would go, it is true, to fill the exchequer, but the process would be performed at some loss of development of production from the soil, the source of all riches in India.

5. The foregoing principles, if correct, seem to show that no unalloyed good can result to a rising country, from a railway or irrigation monopoly profitable perhaps to a few share-holders, and even paying an excess over a guarantee, but beyond a certain point acting injuriously to the development of trade.

Irrigation and Carriage of Produce at cost price.

6. It would appear undesirable to encourage irrigation under a guarantee, but to supply water for cultivation at cost price. Carriage for distribution of the produce at cost price seems equally called for.

Difference between Government Agency and Private enterprise.

7. The difference between private enterprise and Government agency is sufficiently well understood to require no explanation in this paper. Private enterprise may find legitimate scope for operation where there is a profit attended with more or less risk. Private enterprise will also always be most useful where capital is abundant, and the owners desirous to make good use of it in

promoting useful works; but the only case in which such a system can be an unmixed advantage to the country at large, is when competition exists to reduce the earning, sooner or later, to the ordinary rate of profit. A monopoly of the control of the means for stimulating production and distribution of the wealth arising directly from the land by any one set of persons must be injurious to progress, and should be jealously guarded against. Private enterprise can find a wide field for operation in the work resulting from large engineering schemes necessary to the progress of a country, but the administration of such schemes belongs to the country at large, and could not be confined to private persons without injury to some part of the community.

8. Revenue derived from the prosperity of the country is to be preferred to that tending to suppress development. Railway companies find that they can charge high rates on valuable goods. These high charges are a tax on the commodity as much as any custom duty or other impost. It costs no more to carry a ton of firewood than a ton of lead-pencils if the same quantity and weight will go into a wagon, yet a higher rate may be charged owing to the value of the article; pencils must be used by fewer people in consequence and their manufacture restricted, &c.

Revenue.

Opium is a very valuable commodity, but it costs no more for carriage than any other article of like bulk, yet the rate for carriage of opium may be out of all proportion to the cost of its carriage; all the extra profit to the shareholders of a railway for carrying opium is to a certain extent a source of increased taxation to the country at large, for in its absence, a lowering of the price of opium would lead to increased consumption and a larger area being cultivated in India to supply the increased demand.

9. It may be asked in what respect the railway differs from the post office, and if the largest profits are received in one case should

Post Office Revenue.

they not be received in the other. To this it may be replied that no alteration of post office rates would be productive of any extra development to the land; that, comparatively speaking, no capital is locked up in the business, the chief expenditure being in subsidies or payments to railways, steamers, and contractors, which are recovered annually; that letter-writing is a luxury to the million for which they pay, and of which they avail themselves according to their means, the same as they would for books or opera tickets, but no one could say that either of these commodities were a cause, but rather a result of development in the population.

Cheap working.

10. Now there seems to be no question that we should endeavour to do the work expected of railways as cheaply as possible. On this account no more capital should be spent on them than suffices to construct a system calculated to carry all the traffic expected; if more is spent it causes a debt to be incurred for interest, or rates to be higher than they need be, and a corresponding check to expansion of trade and production.

Capital.

11. How much capital should then be spent for the traffic expected? It is evident that what is required is to have least interest on the whole capital to pay; this interest will have to be recovered by rates charged for carriage; these rates are required to be as *low as possible*, but they must include the recovery of all working *expense* as well as *interest*. The more capital expended in a durable machine the less will the working expense be, and *vice versa*. A rate which will recover both these charges will be least when both interest and working charges are at their lowest. The two charges depending on one another can only be a minimum with the work done a maximum, when the two charges are equal.

If one comes to think over this, it is plain that for a certain amount of work, it cannot be done with less of one kind of force than with another. We can change the mode of application of the force, for instance, by doing the work by the aid

of machinery instead of wholly by labour, but the sum of the two efforts of labour and machinery must be equal to the force required to move the load.

Machinery only augments our power of doing a quantity of work by the exact amount of work previously performed in making the machinery, represented by the capital. To invest in more machinery than is required for the work, would be the same as to have a lot of paid labour doing no work at all; to have too little machinery is not to be able to do the whole work at all if it surpasses the power of labour.

The machinery and labour require therefore to be exactly proportioned to one another and to the work. The proportion of machinery will be least when the construction capital is least, and consequently the interest on it. The labour will be least when there is none at all employed on working the machine; but as no machine will work for ever by itself (except the principle of compound interest), it is impossible that this can be considered. Again, if the whole work could have been done by labour alone there could have been no necessity for investing in machinery.

Action of Capital.

12. It is interesting to note the action of capital invested in any undertaking. McCulloch at page 100 of his book on political economy, says, "Suppose profits were at 10 per cent., when a capital of £20,000 is invested in a machine calculated to last one year, the goods must sell for £22,000, viz., £2,000 profit and £20,000 for replacing the machine itself. But if the machine were fitted to last ten years for £22,000, they would only sell for £3,254, viz., £2,000 as profits and £1,254 to accumulate as an annuity for ten years to replace the original capital of £20,000.

"Thus it appears that by introducing a machine constructed with an equal capital which should last ten years instead of one year, the prices of commodities produced by it, would be sunk to about one-seventh of their former price."

Here we have a key to the whole action of a durable capital, and let us see how it affects the railway question in particular.

13. A coolie could carry as a daily duty constantly, say half a hundred weight 10 miles, or 91 ton miles in the year. Take 20 years as the duration of the man's labouring force, and his whole duty will be 1,820 ton miles. He will earn 4 annas a day for taking ¼ ton one mile, or 1 rupee* per ton mile.

Suppose now it be required to take annually 182,000 tons over a mile, this equals the work of 2,000 men constantly, and the cost would be 1,82,000 rupees. A person on undertaking the work with these 2,000 men would require the usual profit, say 5 per cent., for his money thus spent, supposing he had no expense, which is most improbable could be the case.

But suppose the same amount of labour were expended, not in carrying the load, but in making a machine such as a railway (a mile) which should last for ever, and which would work itself, the whole of the men might be dispensed with. But as the machines will not totally last for ever and cannot be made to work without labour, a deduction to replace deterioration and work the line would have to be made. Now the embankments, bridges, and naturally hard substances of this nature will scarcely undergo any change from time and the weather. There will be deterioration from wear and time in the case of the rolling stock, rails, sleepers, woodwork, &c., of buildings, for all of which a life of 20 years is possible to be attained according to the work it is subject to, or quantity and description of material used, in which case the deterioration will then equal the interest on the capital. Also wherever a material will last longer than this the saving will warrant an equal expense in working the line without exceeding the total amount of 5 per cent. for depreciation or working expenses. So that regarding the whole line with its entire plant as one machine, and the working expense including deterioration as the measure of the work taken out of it annually, as long as this is all re-placed in one shape or another, we have a machine that will go on without limit apparently for ever.

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* 1 Rupee = 16 annas; an anna = 12 pies. The rupee may be assumed at an equivalent of 2*s*.

If this working expense is equal to the interest on the capital, which alone will give the least capital for the whole work to be done with least working expense also, we then have the satisfactory result of the same work being done for one-tenth of the former cost, viz., 5 per cent. for the interest, and 5 for working expenses.

14. The dead weight of the man's body as 2 to 1 of the load he carries is not done away with in the train, but is about the same in amount. The rate for carriage would therefore on the data that we have assumed, come to about annas 1·6 or 18 pies. This rate would be somewhat near the average found to actually obtain at present on the Bombay railways, viz., 13 to 16 pies* a ton a mile.

The cost of the lines in India approaches near to the figure representing 2,000 men's daily work for a year, being roughly £17,000.

Accuracy in the above has, however, not been aimed at, but rather an illustration, to show how the railways develop the country. A mile of 5′ 6″ railway, seems to add to the power of it, a force equal to about 2,000 labouring men.

Greatest effect for a fixed Capital in Railways.

15. The doctrine that no more capital should be employed than suffices to carry the traffic with least working expenses, provides for the greatest amount of railway carrying power over the widest area for a fixed capital sunk.

The profits are not required to be more than what would pay the interest on the capital; this will provide for the greatest encouragement of traffic and production.

Each commodity should be charged in proportion to the cost of its own carriage; this will be fair on all production alike.

Taxes on articles of high value should not be levied under the name of railway receipts. Companies, it is true, do so tax them for their own advantage, but Government reaches them through the customs duties. In this lies the great disadvan-

* A pie being equal to half a farthing.

tage of companies where no competition exists to bring things to their natural level.

16. It may not appear to be a question of so much importance when it is remembered that none of the companies have often earned over the guarantee, but still it is one to be considered for the future. One reason why the companies have not earned the guarantee, is the somewhat high cost of the lines which were made by an agency unacquainted with the country in the first instance, the other is very possibly the small encouragement given to producers by the high rates charged: these rates are still no doubt much too high. The third, and no less important cause, is the high rate of guarantee.

Some of the causes of deficient earning for the Capital invested.

The rate of earning on the original capital, is reckoned by Mr. Juliand Danvers at 3½ per cent., or 30 per cent. below the guarantee.

The railways have, it is believed, on the average cost £16,885 a mile.

There seems to be no doubt that money could be commanded at a very much lower rate now, and that with a liberal policy in the matter of rates and a small saving in the cost per mile the lines would easily pay the rate of interest.

Had the rate of interest been 4½ per cent. the deficit would only have been 20 per cent., and with a mileage cost of £13,503, there would, with the same traffic and rates, have been no deficit at all.

Again, the deficit of 1½ per cent. is not shown to be a loss to the general revenues or to the public. It cannot be accepted as in itself proving a former bad policy, either in the style of railway yet provided, or the arrangements, financial or otherwise, connected with the railways in operation.

17. In the first place the extent of cultivation is not shown to have remained stationary or decreased. The land revenue has increased 1½ million in the last 10 years,

Some of the indirect benefits to be put against the deficit.

curiously enough the exact amount of deficit in the railway receipts.

Prices of grain have been equalized, and the interior opened up to imports at a cheaper rate.

The whole capital of the post office, in the way of horses, carts, dawk bungalows, and other establishments on the lines of cart-roads, have been superseded by the railways where they exist, the rate for postage transit being common with the rest of the traffic. Commissariat the same. Bullock trains and all such stock in trade expensive to maintain and work, have been done away with. Troops are moved about at a rapid rate when necessity calls for their services, and undoubtedly we can reduce the number required, in proportion to the celerity with which we can do this.

All these advantages are had for what is possibly a book deficit of about 1½ million (not above 3 per cent. of the total revenue); it becomes clear, however, that any apparent deficit on the railways requires to be very much lessened for such indirect saving.

Indirect benefit to the Community.

Again, if we remember the increase of land revenue eases imperial taxes of every kind, it will be seen that the whole community reap some advantage from the railway system, for those who are rich enough to tax have some of the tax transferred to the land revenue,* while the cultivators get richer in the cotton and corn it pays them to cultivate, when it can be carried cheaply to market.

It might be said that all these advantages would have been attained without the excessive outlay on the particular system adopted, and no deficit have occurred. To this it may be replied that the system best to adopt is that suited to the requirements of the country when it is properly developed. It seems idle to expect that the state funds invested in under-

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* In my own case, it is not without some gratification, that for some cause or another I find the Income-tax has now disappeared. !

takings should be exempted from the temporary loss of interest while works are being made and traffic developed common to all private investments; as long as an extension of railways is going on, it is impossible to see how a deficit can be avoided.

It is pretty certain that no investment of the people's money can be thrown away in railways, which have been considered with ordinary intelligence, and a proper regard to the main arteries of traffic.

Scale of the Lines.

18. As regards the capacity of lines, it is true that the quantity of work performable by lines would be doubled by doubling, but nothing but increasing the gauge can permanently increase the *speed,* which is a large part of the measure of the power. If we are to assume that it would be better to start with the narrowest gauge, the question is, where are we to stop in reducing it to its smallest dimensions; and if it is made to exactly suit the traffic of the undeveloped district, we must immediately commence increasing the number of lines directly the single line is open. It is clear then that we must capitalize in advance even at the cost of increased working expenses in the way of maintenance and fixed charges for some little time.

It is also clear that although a railway to be most economical must have a gauge exactly suited to the traffic, the gauge affecting the whole power of the country cannot always be considered subordinately to one department of political economy alone. *Protection* is as all-important as *production*. The former demands power which can only be got with speed; such power and speed are no less available for the stimulation of the latter.

Rates.

19. The question arises—having determined to make the railways large enough for their ultimate requirements causing a temporary deficit in imperial railway receipts, should endeavours be made by charging the public higher rates, to recover the whole interest and fixed charges, or should you charge rates based

entirely on the proportion of capital which would have been sufficient for the traffic which existed at the time the railway was made.

A sufficient trial has been made to show that the companies, whose efforts may have been legitimately directed primarily to increase their receipts more with reference to their own than any other interests, have failed to realise the guarantee.

This is not to be wondered at. It is impossible for traffic to develop in a short time. It will undoubtedly develop faster by means of the lowest carrying rates, and as it has been shown that the development is not only attended with advantage to all classes, but even by an increase in the quantity of traffic, the sooner it is accomplished the better. The inclusion of excess capital interest on working expense should therefore be avoided.

With this in view in calculating the proper rates to charge, it will not be forgotten that all produce is to be stimulated alike, and that the *capital interest* should equal the working expense. Having found the latter, it is sufficient to add an equal amount for the proportion of capital interest due to the particular commodity, the two going to make up the whole equitable rate chargeable.

Should it be determined to make the trade pay for the extra capital invested, a percentage equal to the actual anticipated deficit might be added, or a percentage bringing up the surplus profit to any figure it is thought can be earned.

The mode of ascertaining the working expense will now be shown, so that we may afterwards do any one of these things.

WORKING EXPENSES.

Working Expenses.

20. The items which go to make up the expenditure of a railway may all be classed under one of the following heads :—

(1) Fuel, grease, water, &c.

(2) Staff of trains and stations.

(3) Machinery and rail renewal.

(4) Maintenance of the works other than rails.

(5) Direction and general charges.

To explain the necessity for the classification, and enable all items of the revenue account to be recognised in regard to the heads under which they come, it is advisable to state that the classification must be with respect to the mode in which the expense on account of each head is liable to vary, according as *the whole traffic* is carried in more or less *number of trains* at higher or lower *speed*, with any *number* of vehicles in each train, and so on. Now let us proceed to ascertain the influence each of these has on the above classified charges.

NUMBER OF TRAINS.

Number of Trains.

21. It is evident that the traffic, which we will take to be a fixed quantity 'Q', may be carried with very great variation in all the above conditions. The thing to be done is to *move a certain quantity of goods or number of passengers over a certain distance in a stated time.*

It is evidently the same thing whether this is done in a large or small number of trains as regards the *power*; for if the whole tractive power required were, say, 100, it is immaterial whether this is divided into two fifties or fifty twos. At the same velocity, therefore, the fuel consumption, which must vary exactly as the power to be overcome or exerted, is constant for the same total load.

(*a*) The number of trains is therefore not to be regulated by the fuel, for it makes little or no difference.

Fuel.

The weight of fuel consumed at the same velocity will be proportional to the weight of the trains, all other things being equal; it seems then that the whole weight of all the trains may be made up of short and light ones burning less coal, or long and heavy burning more.

(*b*) The number of trains in which a traffic is carried, however, directly affects all the items which come under the head of *train staff;* such for instance as should include the wages of *drivers, firemen, guards,* the velocity at which trains travel remaining the same, for the charges must then increase with the increased number of trains.

Train and Station Staff.

The *station staff* should include station-masters, clerks, telegraph signallers, porters, policemen, and all establishments of pointsmen and others required to work the trains.

A line without *stations* is not a common thing; if they are required there must be an establishment to look after them. It makes apparently very little difference to that establishment whether there is one train or a dozen a day. In the former case the establishment must be idle, which cannot be desirable; in the latter there may be so many trains that they can't be got out of the way in time to pass on, and in fact carry the traffic. If there is only traffic enough for one train, the line has been made on a larger scale than required for the traffic; if the traffic causes too large a number of trains to be required to be run, it shows either that it does not carry all the traffic, or that it might carry it better or in greater quantity in larger trains.

It seems then that the staff at stations should bear some proportion to the number of trains in a properly constituted railway; this was to have been expected: then what proportion should the train staff bear to the station staff? They are both necessary to the conduct of the traffic, and dependent on the quantity of it; but if the traffic is carried in a larger number of trains there will be a greater charge for train staff, therefore the *train staff* must not *exceed* the station staff, which is not altered by the number of trains; also it must not be less than it, for it will then show that there not being enough traffic or sufficient number of trains, there is no need for so large a line. There seems nothing for it then but the two must be equal.

The line which will produce this equality will be the one giving continuous employment to the train and station staff during the whole day's work. The 'work done' depends not only on

the number of trains but on the velocity. The hourly pay of one class, however, should equal the hourly pay of the other while useful work is going on, which proposition includes the charges due on both accounts.

(c) The number of trains does not affect the machinery for the same work to be done nor the rails either.

Machinery.

(d) Maintenance of the works other than the rails is not affected by the number of trains in which the whole traffic is made up.

Maintenance.

(e) *Direction, Agency General, &c.*, are not affected by the number of trains, but all these last (c) (d) (e) should be proportioned to the traffic 'Q'.

General.

THE SPEED.

22. (a) The effect of difference of speed on the head of (1) fuel, &c., is slight at considerable difference of velocity.

Speed.

Clarke, at page 310 of his book on railway mechanics, gives the resistance per ton of train at the velocities shown below. These pressures have to be continued evidently for a length of time, increasing as the speed diminishes, and diminishing as the speed increases, in order to cover the same distance. The total pressure which corresponds to the fuel consumption will be as the pressure and the time it acts. This would give as shown below :—

Miles an hour.	lbs. Resistance per ton of train on level.	Time over 70 miles, in hours.	Total ratio.
10	8·6	7·	59·2
20	10·3	3·5	36·
30	13·2	2·33	30·
40	17·3	1·75	30·3
50	22·6	1·4	31·64
60	29·	1·16	33·
65	32·7	1·07	35·
70	36·6	1·	37·

It will be seen that the pressure rises rapidly, but as the time diminishes the compound ratio shows that very little variation takes place in velocities differing only in a small degree.

It is worthy of note also that the least fuel consumption will be at from 25 to 30 miles an hour on the level, other things remaining the same.

(*b*) The pressure is made up of *friction, wind resistance,* and on inclines, gravity; now gravity is constant for the same line, and friction is not altered by the speed; the only increase of pressure from greater velocity arises from the wind, provided the road is somewhat straight and in good order, which is a matter of maintenance common to all lines. The wind resistance increases with the square of the velocity, and this forms the increased pressure.

It is an object to have as large loads with as little wind resistance as possible; but it is also an object to carry at a certain speed to get the proper number of trains over the line. What greatest speed will give the most fuel expenditure on overcoming the friction and gravity, and least on the wind? Evidently when the fuel expended on either is half, the whole or wind resistance equals friction and gravity.

On a level it would require a train of 300 tons to travel approximately at 35 miles an hour for these to be equal. A smaller train would travel, in regard to the fuel only, economically faster.

Train and Station Staff.

(*c*) The effect of the speed on the train staff and station staff (2) is easily understood. If the trains are accelerated it must be evident that the driving, &c., &c., must cost less, for a smaller number of hours will be spent in driving, and you may reduce your charge on that account for the whole quantity of traffic 'Q'. The same of all the train staff.

It was previously shown that the station staff should be proportional to the traffic 'Q' and equal to the train staff. This will be the case when the line is properly constituted and

suited to the quantity of traffic as shown before, and the proper number of trains are run.

(*d*) Some adjustment is also possible in the same gauge, for should there be few trains compared to the number of stations and the expense of the latter in excess, it will be found economical to employ all the staff you can on the trains, such as ticket-takers, greasemen, &c., and carry them with you, as is sometimes done, Major F. S. Taylor tells us, in America, thus equalising the two staffs. This is a matter of management, but referred to in order to show clearly that both the station and train staff vary inversely as the velocity. For faster trains there must be a saving in these two items, and for slower more expense to take the quantity of traffic 'Q'.

(*e*) Before going further it is necessary to state that as the same quantity of traffic may be taken in a variable number of trains at variable speed, the two conditions cannot be considered separately and independently.

The charge per mile for train and station staff will evidently vary inversely as the speed for every ton of goods, but for the whole quantity 'Q' it is evident that the whole train and station staff charge which appears in the revenue account will be the charge for the train at the particular speed multiplied by the number of trains in which the total quantity 'Q' is carried. By decreasing the loads of trains the velocity may be considerably increased, and the charge per train mile will be considerably decreased; but in proportion as the load is decreased to attain increased velocity, the number of trains must be increased to carry the same total traffic 'Q'; so it appears that the cost of train and station staff for the whole quantity 'Q' will be constant, whatever the size of the trains on the same line.

(*f*) The effect of the velocity in demolishing the rolling stock and rails.

It seems unnecessary to enter into the principles of dynamics, which enable forces to be estimated by comparison with the force of gravity.

Any one desiring to ascertain for themselves the laws relating to motion may easily consult books on the subject. From them they will gather that all accelerated force varies in intensity with the square of the time or velocity; that the velocity resulting from a constant force acting in equal times is proportional to the time; and that the space passed over by the agency of an accelerating force is as the square of the time. Now the intensity of the force tending to demolish the stock and rails as above varies as the square of the velocity, but the total demolition will take place in proportion, not to the intensity only, but to the time such force is in action.

For instance, 100 blows of 2 lbs. each per second, will do no more harm than 50 blows of 4 lbs each: the demolition results from the blow, which may be considered a pressure for an infinitely short time, but that short time, whatever it is, must be halved for double the velocity. The wheels rest only for half the time they did before, and the unevenness of the road, which caused a rise or fall and a certain amount of momentum to be imparted to the rail, will be distributed over double the length of rail. Again, the effect on the rolling stock is much easier understood.

The velocity being accelerated the trains are less time on the road. Thus if the intensity of the blows varies as the square of the velocity, the time they are in action varies inversely as the velocity, so that the whole demolition varies as the velocity simply.

In this manner, though it is true the intensity of the force is greater for increased velocity in proportion to the square of it *while it is acting*, still as we have only a fixed quantity of traffic 'Q' to carry, the trains are not so long on the road, and are not subject to the demolishing force as long as before. The demolition or wear of the engines is exactly proportional to the weight and the velocity of the load; but for the whole quantity of traffic 'Q' the weight to be drawn by all the engines will be constant, and the wear dependent on the velocity only. It seems immaterial whether we distribute the

wear and tear of the whole of the engines between many or few, a fixed amount of wear must take place for a certain quantity of traffic to be conveyed at a certain velocity. The wear will be increased in proportion to the increased velocity, other things being the same.

Rails.

(g) Now as regards the rails, it is evident that if the rolling stock by its motion causes blows to the rails which they are strong enough to sustain, the forces given and received are simply action and reaction, which must be equal in both. If the rail has been designed too weak, it will not stand the weight and velocity of the rolling stock; the one must be proportioned to the other in such a way that the annual deterioration of both may be least. They are subject to the same destructive forces, and the amount varies equally with every variation of both them. It is no use to have the rail proportioned too heavy or too light. If it is too heavy there will be little total wear compared to the total wear of the rolling stock, and in that case a lighter rail would have required less capital spent on it and consequently interest to be paid. The same argument applies to the rolling stock; if it is too heavy for the traffic, it will last longer, but capital will have been uselessly spent on it. The sum of the repairs or demolitions will be constant for the same quantity of traffic 'Q'. It is quite clear that a rail must fail, not by the waste of the whole material, for when it gets below a certain strength for its work it has not lost much of its weight, and if the rail were sold it would fetch a good price as old iron. It fails, because it gets crushed with the repeated blows; its sectional area is weakened from constant grinding of wheels, by the action of the weather in causing rust—a constant force in operation not prevented by the apparently clean state of well-used rails but only undiscerned by the eye. The work to be got out of the rails is required to be a maximum, while the whole deterioration is required to be least, and also the deterioration from time and the weather should be least for the work done. The three actions taking place are dependent on the velocity for the blows, the weight

for the grinding, the weather for the rust. The whole deterioration for the two former will be as the compound ratio of velocity and weight; and since an acceleration of velocity may be made with a corresponding decrease in weight, and *vice versâ*, without producing any change in the actual total wear from the rolling load in the same time, the velocity and loads will be economically regulated so as to produce least wear in that period from both these causes when the wear resulting from them is equal in each case.

Again, the wear from the two effects of the whole rolling load and the weather will in the *same time* be best regulated, giving least expense from both, when enough iron only is used with least surface exposed to the action of the air to cause the failure to ensue from both simultaneously.

The deterioration from both causes should therefore be equal.

The destroying effects of the various elements acting on the rails will then be in this proportion—

Velocity	1
Weight	1
Time and weather	2
	4

It is clear from this that the deterioration from the ton mileage forms only half of the whole.

This remark applies equally to the rolling stock, for as regards the deterioration from time, whatever the action is on the engines and vehicles, it is the measure of the life.

Maintenance.

(*h*) The effect of velocity on the *maintenance* (4) *of works other than rails* is as the velocity. Ballast is disturbed and the road requires constantly packing up, but owing to the influences of the weather some of this would have to be done whatever the number of trains travelling at any velocity. The velocity for any quantity 'Q' is however fixed, and the maintenance should in like manner therefore be equally due to the traffic and the

weather. This is effected by proportioning the gauge to the work, making it only broad enough and no more.

Effect of velocity on *general charges* and direction, &c. (5). It is manifest that these are not directly affected, but they should, like all the rest, be proportional to the quantity of traffic 'Q'.

THE INFLUENCE OF THE NUMBER OF VEHICLES PER TRAIN ON THE HEADS OF THE REVENUE ACCOUNT.

23. (*a*) *Fuel and Grease, Water,* &c. (1)—It is evident that to convey the quantity of traffic 'Q' it requires a certain number of vehicles which require a certain power. No method has yet been discovered by which the loads can be transported by conveyances or other means, having no weight; whatever the weight of the conveyance, it has to be included in the power. This dead weight as it is called, is made up of engines, tenders, brakes, and vehicles. Now the former supply all the tractive force. The weight they will draw is proportional to their own weight. You cannot increase the number of vehicles an engine will draw, supposing it to just be able to move, without increasing its weight.

A certain amount of weight of engines exactly proportional to the quantity of traffic 'Q' is as indispensable to the whole weight as the wagons in which to carry the goods and passengers.

As the weight of engines is entirely proportional to the total load indispensable to draw the traffic, they may be considered in the general dead weight.

The influence of velocity has already been shown to cause no appreciable excess consumption of fuel for the whole quantity of traffic 'Q,' but in the case of an engine loaded so as to be able only just to move, it is clear that it could acquire no velocity at all worth speaking of, but if we remove the wagons one by one, since the power of the engine remains the same, the velocity will continually augment till it gains the greatest velocity when there are no wagons left.

Where a certain velocity is desirable then, the load must be considerably reduced, and the load of the engine thus becomes determined, not alone by its greatest power of traction, but by the greatest load it will draw at the greatest or any required *speed.*

As the load increases the speed diminishes, and *vice versâ*; the proportion of engine weight to train weight is in no way affected by introducing the element of velocity. As in one case, however, the whole fuel is exerted to *just* move a maximum load, whereas in the other case it is used to produce maximum velocity with maximum load, it is clear that *the number of vehicles must be so limited as to give only half the fuel consumption due to load and half to the velocity to produce the effect of the largest load taken over the longest distance in the shortest time.*

It has now been shown that an augmentation of velocity or load must for the *same train* cause more fuel consumption per hour, but whatever our loads and velocities, we have only the same quantity of total traffic 'Q' to carry, and the gross load being a fixed amount and absorbing half the fuel, the velocity at which we should carry it and depending on the other half of the fuel would be constant, so that for a line properly constituted to carry the quantity 'Q,' the whole fuel consumption is not altered, but the fuel consumption per train is, in the compound ratio of the weight and the velocity.

Train and Station Staff.

(*b*) As far as the train and station staff (2) is concerned, the whole number of vehicles has to be moved to carry the traffic; if one train is shorter, another will be longer, so that there will be no alteration to the whole head of revenue account on that item; *each train* would bear its proportion, depending on the number of vehicles comprising it.

Machinery.

(*c*) Machinery and rails (3) will not be increased or diminished by the number of vehicles per train for the whole quantity 'Q,' but each train will wear the rails and rolling stock in proportion to its weight and velocity.

(*d*) Maintenance of the works, &c., other than the rails (4) unaffected. The charge for a train will be a part of the whole proportionate to the number of vehicles or the speed tons.

Other Works.

Direction general, &c., will be unaffected as before; the proportion due to the train will be that portion of the whole due to the weight and velocity, compared to the whole weight and velocity for the whole line.

It will be seen that in these conditions regarding the vehicles per train, nothing affects the general heads of the revenue account.

But the charge for trains is made up of some items which vary as the weight and velocity, while others should depend on the whole quantity of traffic.

24. There are now two things to consider,—the proportion of the charges of the revenue expenditure for the whole line (1), and the proportion of charges for one train under any conditions (2).

Revenue Charges, total and per train.

ABSTRACT SHOWING THE HEADS OF ACCOUNT AND THE MODE IN WHICH THEY VARY.

Total Revenue Account.

Staff of trains and stations—Varying as the velocity inversely and directly as the number of trains.

Machinery and rail renewals—Velocity.

Fuel, grease, water, &c.—Varying as the ton mileage.

Maintenance of works other than rails—Half constant charges and half varying as velocity.

General agency, direction, &c.—Varying as the quantity of traffic 'Q.'

Now here we have the whole revenue expenditure classed under the heads varying in the same degree. No single one of these can be done without; they all differ in their character and mode of incidence, and expenditure on one is no use without a

proportional expenditure on the others. They make up the whole charges for working the traffic, and there are none other that vary in any different way or that will form another class.

It remains to see how the incidence of the different charges occurs.

REGARDING THE MODE OF INCIDENCE OF CHARGES PER TRAIN.

Proportion of Train Charges.

(*a*) *Train and Station Staff.*—The gauge which will produce an equality of these is the one calculated to prove economical. The charge per mile for a ton conveyed will be least for the former when the velocity and size of trains is greatest and number of trains least, while for the latter to be least the velocity and weight of trains should be greatest, but their number also greatest.

The weight and velocity of trains being required a maximum in both cases the variable may be taken as the number of trains simply.

(*b*) Then whatever the size of the line may be, it seems that a fixed proportion of expense must be incurred for train and station staff, and that the portion of expense increasing with the *number* of trains on the same line, while it produces no extra cost per ton mile for train staff, produces a reduction per ton mile in the expense for station staff in exact ratio. Thus there will be a point when the line is exactly suited to the traffic when the two charges will be equal, *i. e.*, when the line is fully employed.

(*c*) By taking the expense of train staff to be represented by 1 the station staff can also be taken as 1, total 2.

(*d*) *Repairs of Stock and Rails.*—For the same traffic this depends on the velocity. The only other item of cost depending on the velocity and inversely on it, is for train and station staff, as just shown.

The charge per ton over a mile for repairs will be lessened for a small velocity, while the staff will be increased in the

same train in the same ratio and *vice versâ*. Change in one thus resulting in a corresponding change in the other, the sum of the two will be constant per ton mile.

Again, a low velocity on a small gauge will produce a smaller cost for repair on account of that velocity, but the cost of the train and station staff *if considered a fixed quantity for the work done* must be larger per train on a broader gauge. By increasing the gauge for the same velocity the whole charge for the two items of staff and repairs will remain the same per ton mile, but the repairs will increase till a point when the two are equal, when the least charge will be incurred on both items per ton of the train. This then becomes another condition for the most economical gauge. If the former charges are represented by 2 the repairs must also be 2, total 4.

(*e*) If the charge per train mile for the train and station staff and repairs to stock and rails is represented by 4, it is clear that the charge for *fuel, grease, water, &c.*,—a fixed quantity of which are required for every ton hauled,—a mile, will also be represented by 4; for while the charge per ton mile of the train will remain stationary for the fuel, &c., the charge for staff and repairs will be diminished for every ton weight added to the train after the first ton, while the cost of the train will be increased in a less ratio. The weight of the train may consequently be augmented till the cost per ton for the former charges and for fuel, &c., are equal, when the total cost and cost for both classes of items will be least; after that point is reached the addition of another ton will cause the decreased cost per ton to be exactly proportional to the increased cost of the whole train, so that no advantage will accrue from a longer train than results from equality of the fuel, &c., with the staff and repair charges.

The whole charge for the train incurred on the line may therefore be represented by 8, on a gauge which will allow of the proportions being maintained.

This shows that it is a fallacy to assume that longest trains and greatest power of traction in the engines is the *sine quâ non* of the design of a line.

Greatest power of traction.

Should it be found that the line has been made on too small a scale, these expedients may be necessary in order to *perform the quantity of work*, but they can have no place in determining the gauge.

(*f*) Now for the charges not directly incurred on the trains *when running*. These are *maintenance* of the works, such as bridges, embankments, &c., *general*, *agency*, and in fact all the charges incurred which are not variable, as velocity, weight, &c., but which have to be recovered by charge against the work performed by the trains, and may be considered to vary as the time they are working.

Such may be called fixed charges, for want of a better term. They are however in reality liable to certain alterations, inasmuch as they should be exactly proportionate to the whole traffic, whatever it is; but in a line not in full work this is in practice difficult to obtain, though something may be done towards it by careful management, in some classes of charges.

The whole charge for the trains should vary as the number of them, while the charge for agency, &c., per train will vary inversely as the number of them. The former requires that the *number* should be least, while the latter requires that the number should be greatest for the gross sum of the two charges and the charge per train to be least.

The proportion of fixed charges, &c., debitable to each train will depend on the whole number of trains. The charge per train will diminish rapidly as the number of trains is increased from 1, when the whole has to be recovered from a single train, to a point when the number of trains brings the 'fixed' charges per train to an equality with the charges for the train; while the cost of the whole gross working charges is not nearly so rapidly increased by the additional trains.

When equality is reached, the number of trains being increased the increased gross charge for the line and each train would be exactly in proportion to the increased number of trains, so that no diminution of cost per train for fixed charges would then occur.

Thus the proportion of fixed charges due to a train is a portion equal to the charge for the train itself, for it is immaterial whether two or more trains are used to carry the same quantity of traffic, with the velocity and weight economically regulated.

(g) Hence it is deduced that the other charges being represented by 8, the agency, general, and fixed charges, should also be 8, and we arrive at the following proportion:—

Proportion of Train Expenditure on a suitable Gauge.

Train Staff	1
Station do.	1
	2
Repairs—Rolling Stock and Rails...	2
	4
Fuel, Water, &c.	4
	8
General Agency, &c.—Maintenance, Miscellaneous	8
Total cost......	16

Difference between the Train and Revenue Account proportion.

25. Now in what respect will these proportions diverge from the principal heads of the *revenue account* for lines on different gauges?

It must be remembered that the force employed directly on the trains in producing motion is the *fuel*, and that its duty is measurable by weight moved over a distance; the work may be performed in any time, and be changed from a great weight over a small distance to small weight over a greater.

Ton mile Charges.

(*a*) The cost per mile for a ton must therefore be constant whatever the speed. For suppose the velocity to be doubled, since the fuel will only produce a certain amount of steam in an hour, and a fixed quantity is required to move a ton a mile, it is clear that the distance being doubled in the hour, the fuel can only take a train of half the weight. The cost of the train per hour will in both cases remain the same, the distance travelled however will be double, so the train charge must be half, but the weight conveyed is also half; thus the charge per ton conveyed a mile remains the same for fuel.

Stock and Rails.

(*b*) But this is equally true as regards the stock and rails repairs, for if the train is half the weight and travels at double the velocity, the wear will be the same per hour for the train, but the wear per mile will be half; and as the weight of the train is half, the charge per ton mile will be the same as before.

Train and Station Staff.

(*c*) It is also equally true of the train and station staff, each of which will be a constant charge per hour; with a train of half the weight and double the velocity the rate per mile will be half, but so also will the weight of the train, and the rate per ton remains the same.

Fixed Charges.

(*d*) Again, the fixed charges are not directly affected by the size and velocity of the train, for to carry a fixed quantity of traffic 'Q' over a certain distance, say in a year—if trains *are* shorter with greater velocity, more of them must be employed for the total quantity of work and *vice versâ*; and since the cost of a ton over a mile is unaffected by the speed, under these circumstances the fixed charges have simply to be proportioned to the gross tonnage.

26. The charges appearing in the revenue account are for the gross amount of traffic, or the whole work performed, and since the mode of incidence of them does not alter the charge for a ton over a mile, and it costs a fixed amount of every one

of the heads of revenue account to each ton, it would seem that the whole gross charges should be in the same proportion as the train charges. In fact, however, the only proportion that will stand good, is that for fuel, grease, water, &c., which in both cases will be one-fourth of the whole, and is independent of the velocity and number of trains in which the whole traffic is carried. Also, since water, grease, and oil form one-fifth* of this expense, the amount due to *fuel*, the prime mover, is $\frac{4}{5} \times$ 25, or 20 per cent., for the fuel only.

27. As regards the (2) train and station staff on one hand and the (3) repairs to stock and rails on the other, the figures representing them in the train proportions have to be evidently modified for the *number* of trains.

Equality of 'Velocity and Number' charges.

The figures referred to treat only of the expense due to the velocity of the particular train, while the revenue account treats of these expenses multiplied by the number of trains. The same total work of the line per annum may be done in a small number of trains of great weight or a large number of smaller weight; in one case there will be a less expense for the *staff* of them for their number, but a greater expense on account of their slower velocity per mile, and in the other case there will be a larger expense for the number of trains, but the expense per mile owing to greater velocity will be less. The charge for the total quantity must therefore, under all circumstances, remain constant, and it must be possible to arrange a velocity and the number of trains so as to give an equality to the charge due on account of the number of trains to that on account of the velocity which will give a maximum velocity with greatest number of trains, thus giving the greatest effect of the line.

This is to be effected by proportioning the gauge to the traffic so that trains will always be running.

Again, as before, the repairs to stock and rails per train will be inversely as the number of them, and directly as the weight

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* The reason for this proportion is investigated in Art. 32 *a*.

and velocity of each. The total repair for the whole quantity of traffic must be therefore constant, and it must be possible to arrange the number of trains and the velocity so that half the expense is due to the velocity and half to the number of the trains, which will also give least repair per train and maximum velocity and weight in the whole number of trains.

The equal figures in the proportions of each train (Art. 24 *g*) representing the above items must be doubled to represent the totals in the revenue account.

This can more clearly be appreciated when we remember that for a single piece of line between two stations only one train can occupy it at a time, and for a train each way to be *constantly* running without a moment's interval one must wait till the other arrives to keep up a continual service. The work done would thus far depend on 'velocity' and 'number' charges for the total work as regards staff and repairs in equal portions, and would cost no more or less with trains of double the weight at double the length of time each on the road, and so on.

Constant service an indication of maximum work for minimum power.

28. The maximum that a train can do in the day's work is when it runs continually for 12 hours at the economical speed for the line with the maximum load due for it. This must evidently be the same thing as twelve such trains running a distance from one station to another equal to the velocity for the line. A constant service could only be kept going under such an arrangement, and on a single line only six can go in each direction. The full work of a line is therefore twelve trains over every mile in the day's work or the equivalent.

A fixed quantity of traffic may be carried in a larger number of trains, but the velocity must be higher and load lighter and *vice versâ*; the train and station staff will be less per train mile if the velocity is increased, but the number of trains being necessarily increased in the same proportion to do the whole work, the total train and station staff will be constant, and since it is

in the compound ratio of the charge per train mile and number of trains, they will both be greatest when the ratios are equal (for the sides of a rectangular figure for a given area will both be greatest when the figure is a square). When the charge per mile for the train staff, &c., is greatest, the train will be heaviest, and when the charge per mile for the number of trains is greatest the number of trains will be greatest. Thus the greatest weight of trains and velocity occurs when the two charges are equal; this argument applies to the repairs per train mile, which all vary with the velocity directly and weight of trains inversely. The repairs for the whole quantity of traffic will be as the compound ratio of the two, which will always be constant and a maximum when the two are equal, giving the greatest weight of trains with greatest number of them for the day's work.

The gauge which will do this, giving the greatest effect for velocity and weight of trains, will be the one which will do the required work in the shortest time.

In practice the shortest time common to all operations might best be referred to the day's work, and the power exerted to the weight taken in miles per hour over a portion of line between two crossing stations.

Similar gauges and constructions.

29. To see the effect of altering similarly constructed railways. (*a*) The *train staff* charges per train will be as the gauge; also according as the train travels faster or slower the charge per mile for the train must be less or greater. The velocity varies as the gauge and so does the train weight. The charge per train owing to the velocity will be comparatively greater in a small gauge, but the charge for a smaller or less highly paid staff per train in proportion to the gauge reduces the cost to a constant, and the less weight of train in proportion to the gauge makes the charge per ton of it also a constant.

(*b*) Next, each *station charge* must be in proportion to the gauge, and consequently smaller on a smaller gauge; but the

number of them increases in proportion to the gauge, so that the whole charge is a constant.

The number of crossing places or stations must be exactly inversely as the velocity, that is, in a line giving double the velocity the crossing places will be half in number, which will be more easily understood when we remember that to cross trains every hour is requisite, and the distance travelled in that time will be proportional to the velocity or the gauge.

Thus it appears that the alteration of gauge gives a greater number of smaller trains which are a longer time on the road, and that a greater number of smaller stations nearer together are required to assist in the work, and *vice versâ*.

Stock and Rails.

(*c*) Then as regards repairs of stock and rails. The weights and velocities vary as the gauge, for this arrangement provides for the greatest weight over the greatest distance in a given time.

The effect produced on the stock, rails, and P. W. material per ton over a mile varies simply as the velocity, whatever the gauge. Thus in a gauge half as broad the whole destructive effect will be half as much; but as only half the weight also is carried, and the total work done is only one-fourth of that on the larger gauge, the total effect per ton mile remains unchanged.

As regards the question of dead weight see further on.

(*d*) Then as regards all the fuel, &c., and fixed charges. These must vary as the total ton mileage, and are consequently unaffected by the detailed arrangement by which the work is done, so that from the above it seems that it must cost the same amount to convey a ton a mile by whatever gauge it is performed.

Train proportion on different gauges.

30. Now although the revenue account proportions for any similar constructed gauge must remain the same—Will the train proportions remain the same in every case?

To put this clearly take a gauge half as broad.

(*a*) Now the *train staff* for each train must appear theoretically to remain at the same expense per hour whether it is employed on a large train or a small one, and since the velocity in the same time is less on the smaller, one would suppose that the expense per train mile of that item must be more, and that since the load and velocity would only be, say, half, the expense per ton mile would be four times as much.

It is however highly improbable that the expense per hour for such train staff is constant in two different gauges.

This will be evident if we only take the item of fuel and grease for the engine while running. These must be expended exactly in proportion to the weight required to be moved over a distance in the hour, and if it takes one man to stoke and oil and water in a small gauge using 20 lbs. of fuel to the mile, and he is fully employed, it is impossible he can do a train of a gauge travelling two miles in the same time requiring 40 lbs. to the mile, and extended grease and water operations, so that an additional fireman, or more frequent relief, becomes absolutely necessary. Again, on a line affording higher speed and more trains the driver must be a more efficient man than will be needed for a small line and slower speed:* his wages must be in proportion to the energy and intelligence demanded. Again, in the large and heavy goods' trains of bigger gauges additional brake vans are provided for the safety of the train and economy of time, in stoppages, &c., all of which are not of so much moment in lighter trains, and when these things are considered, it will be evident that the *train staff charge per hour* per train is not *a fixed charge* for different gauges, but that the charge for a ton one mile is so fixed we have seen before, and that the charge per hour should be also fixed militates against this.

(*b*) The *station staff* can also not be a fixed charge per hour for stations, which is evident from the size of the trains being so much less.

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* It is here assumed that the circumstances necessitating a larger line call for increased facility in every way, such as more frequent service at greater speed, though the total work done may be proportionate.

All the remarks above made, in regard to the intelligence required and the higher wages resulting, apply equally to every service, the station staff included. There will not be so much greasing of vehicles to do, there will be lighter trains to shunt, requiring fewer porters, signallers, clerks, &c. &c., and there will be fewer customers to serve.

Thus in both cases train and station staff expense should exactly correspond per hour with the work to be done in that time, so that no variation can take place in the proportions here indicated on account of the gauge, with proper regulation of wages and people employed.

(c) The *repairs* and cost of *fuel* in a train are exactly in proportion to the work performed in a given time, so that it appears undoubted that the proportions of train expenditure in this and all other respects must, with proper management, be the same, whatever the gauge. Summarising then, it seems that the cost per ton will always remain the same, but the same quantity of work will be done in smaller lines in a larger number of smaller trains, a longer time being occupied on the road.

31. To revert now to Art. 26. It will be observed that the *fuel, grease, water, and oil* form one-fourth of the whole train expense, whatever its length, and the total revenue expenditure for the whole traffic on this account not being affected by the number, length, and velocity of the individual trains, the total proportion of these items in the revenue account remains the same, *viz.*, one-fourth; but while the expense on ton mileage, including all the items besides fuel, determines the size of each train for its velocity, the expense to be incurred on *fuel only* is the one to which the velocity is precisely referable. The items of oil, grease, &c., are to overcome a certain amount of friction quite independent of velocity, but which if not employed sufficiently, would result in a greater consumption of fuel and wear of vehicles and engines from friction; they are consequently correctly included in the ton mileage class of charges determining the length of trains; also the water is indispensa-

ble to the motion of the train, and the quantity expended must vary exactly with the work done.

None of these items, however, can in themselves produce motion, and though they enter into the expense of trains in proportion to their size, it has been shown that the size and number of trains has no effect on the total consumption of those articles and the expense for them appearing in the revenue account, so that the only direct measure of the work of the *whole line* and *each train* is the *fuel*, and it has been shown to correspond in all cases with *one-fifth* of the whole expense.

From what has been said, it seems evident that the cost of trains and their number on every gauge and for every purpose may vary, but the expense per ton mile will, with proper regard for economical administration, remain the same invariably.

The revenue account deals with the whole expenditure in performing the gross ton mileage. The classes of it depending on the same, variable, are all necessary to the work, and in order to get the best effect from the general design of the railway, should all be equally brought into action.

The proportions of trains (Art. 24 *g*) are—

$12\frac{1}{2}$	Staff.
$12\frac{1}{2}$	Repair.
25	Fuel, grease, water.
50	General, agency, maintenance, &c.
100	

Also the total quantity of *fuel* only for the whole line is (Art. 26) 20 per cent.

32. But it is necessary first to investigate the reason why grease, oil, and water appear to form one-fourth of the cost of the fuel or one-fifth of the whole cost of all these items together, which is the same thing.

Proportion of fuel to grease, oil, and water.

They are all items varying with the ton mileage exactly, so the question naturally arises, why separate them at all?

The fact is, however, that for the same total expense on these items, the work done may be very different.

An increased proportion of fuel to the other items may mean increased velocity and less load, and *vice versâ*, or it may mean the same velocity with increased load according as the quantity or price for the same quality of coal affect the length of the trains. The quantity of grease, oil, and water being increased, or diminished, could not in itself *pro tanto* produce less or more velocity, but its price being lessened, would allow more to be spent on fuel for the same economical load, and hence increased velocity would result.

The work done may be measured by the weight, velocity, or both these elements, in the consideration of the same train, and it will be easier to refer first only to the velocity.

Suppose it possible to do without water, grease, and oil, or that they cost nothing, the proportion of train expense would still be as before—

Train and station staff	1
Repairs	1
	2
Fuel	2
Total ...	4

Now the introduction of a charge for grease, oil, and water, if we are to maintain the same proportion, must diminish the quantity of fuel possible to be expended with the same weight of train, and consequently the velocity.

There will then be an excess in train and station staff per train mile and a corresponding decrease in repairs per train mile, so that no excess cost per ton will result, but the velocity possible will make the train longer on the road.

It seems clear, then, that we may be able to maintain the velocity as it was before without any extra expense by now reducing the weight of the train.

The actual velocity charge per mile, *i.e.*, for staff, will be inversely as the velocity, and to maintain this the same, the actual proportion of expense for work done by the train to the velocity charge being as 4 to 1, the proportion of the element tend-

ing to reduce the load for the same total work done by the train, and which depends exactly on the fuel used, must be in the inverse ratio, or $\frac{1}{4}$ to 1.

The element tending to require the shortening of the train to maintain the velocity is the grease, water, and oil, and the total work done is represented in this case by the fuel, therefore the former should be one-fourth the latter in cost.

This seems to be the only solution of what is apparently an established fact.

Comparison of Train and Total Revenue Charges.

33. The train proportions shown below are evidently identical:—

$$\left.\begin{array}{ll} \text{I. } \ldots\ldots\ldots\ldots & 12\tfrac{1}{2} \\ \text{II. } \ldots\ldots\ldots\ldots & 12\tfrac{1}{2} \\ \text{III. } \ldots\ldots\ldots\ldots & 25 \\ \text{IV. } \ldots\ldots\ldots\ldots & 50 \\ \hline & 100 \end{array}\right\} \times \frac{4}{5} = \left\{\begin{array}{l} 10 \text{ Train and station staff.} \\ 10 \text{ Repairs, stock and rails.} \\ 20 \text{ Fuel, grease, oil.} \\ 40 \text{ Administration \& General.} \\ \hline 80 \end{array}\right.$$

Also this is on the understanding that the two first of the charges, which vary as the velocity and number of trains, are so regulated as to give an equality for both elements (Art. 27); so that the revenue account proportion, including all the trains, will have the two first items of the above doubled; and allowing the figure 20 then to refer only to fuel and the other charges to be included in General, we get the proportions as follows:—

20	Train and station staff.
20	Repairs, stock and rails.
20	Fuel only.
40	All other charges.
100	

Now the above referring to the proportions for all the trains is the same, provided the line is in full work, as the proportion for a train obtained by making half the train and station staff a fixed charge for any one train. Half the repairs to stock and

rails a fixed charge, both these being due to the number of the trains: thus making 'all other charges' 60 per cent. Deducting from them the locomotive and traffic stores which are 10 per cent., and adding them to the train charge, makes the total train charge 50 per cent. and the fixed charge 50 per cent.

This agrees with Art. 24 (*g*), and it will now be satisfactory if we can determine the constituents of the last charge of 40 per cent. It will include only such charges as should vary with the whole traffic together, the line being in full work with 12 trains, or the equivalent, a day, &c.

Relation of Maintenance of Sleepers, Ballast, &c., to Repairs of Rolling Stock.

34. (*a*) Maintenance bears a relation to, and is dependent on, the rolling stock and rails in this way.

The same loads may be carried on a road made very broad to allow large wagon bodies to pass along it, or very narrow to allow narrow wagons to pass. The smaller the embankments and bridges, &c., and the less material in them, the less surface and general repair they will require for that element, provided they are not subject to a greater amount of work than the material will stand, that is, provided the work to be expected is proportioned to the means of doing it.

It must be understood that the two ways of doing the same amount of work are now referred to, and not two designs for an arrangement for doing different quantities of work.

If the wagons are projected much beyond the wheels they will be unstable, and the wear of the rails will be more, and there will be more wear to the stock than if they were quite stable for their breadth. This kind of stock demanding possibly equally broad embankments, bridges, &c., with a gauge giving greater stability for the width of the wagons may, therefore, be said to have in no way cheapened the construction or maintenance of the way and works. Such overbalanced rolling stock causing a disproportion between the stock and rails will give an apparent saving in the sleepers and ballast owing to their smaller breadth; but the weights of the vehicles are very

likely much too heavy for the gauge, and for the same velocity in both cases will wear themselves by as much more as there is less material to renew in the sleepers and ballast, as will be seen further on, so that no saving occurs in this class of stock. But the same amount of work would have been got out of a stable class of stock owing to superior velocity, and the embankments, bridges, &c., might have been narrower and cost less to construct, causing a less charge for interest on those parts of the railway.

The embankments, &c., &c., may, therefore, be said to be able to be diminished in width as it is possible to increase the velocity for stable rolling stock on the same line. As the velocity increases so the expense of repair of rolling stock and rails increases; while as the embankments, &c., diminish, so the repairs of them diminish; the sum of the two for a given quantity of work must therefore be constant, and it must be possible to arrange a velocity and gauge which will give the two charges equal.

This argument will not sanction the inclusion of the sleepers and permanent way fastenings, or the rails, for they can *neither* diminish for increased velocity but must be increased to suit it.

This equality can only occur with greatest effect when the gauge provides for perfectly stable stock, for then alone will the embankments, &c., be narrowest for maximum velocity.

It seems then that 10 per cent. of the working expense should be absorbed in renewals of sleepers, keys, ballast, &c., which are the quickly perishable materials, all the others being little changeable by the wear of traffic or the weather.

Art. 36*f* will show that 10 per cent. is due to traffic and locomotive stores used in trains and at stations.

Administration.

(*b*) Ten per cent. is due to administration, &c.

This class of charge is necessary in every department, and cannot vary directly with the traffic always on any particular line at any time, but it should be proportional nevertheless to the whole work to be done on the average.

The economical condition requires for the proportion of such charges to be least on the work done, that the work should be constantly in operation at the same rate in both cases. The pay of salaried officials is constant for time. The work on the line to cost least for that item, therefore, must always be going on at the maximum for the line. When such is the case, half the fuel will be employed to produce maximum velocity and the other maximum load. Now, whatever the traffic may be in amount, if it entails the construction of a railway, we can always construct it on such a scale that the line may normally be working at its maximum speed and loads constantly. The cost of the means for effecting the *work* answering to the weight is 10 per cent. of the working expenses for half the fuel.

For a gauge to take double the quantity over the same distance the loads will be increased, and velocities increased as $\sqrt{2} = 1{\cdot}4$ times. The whole quantity of fuel expended, however, will be simply double, and so will all the other charges of the line; the administration charge amongst them, then, will vary as the charge for the fuel, and only the portion of it due to the weight irrespective of the velocity, when reference is made to different gauges for the purpose.

The work done* represented by 10 per cent. of the working charge for weight moved will therefore be a maximum, and the administration charge depending on it a minimum when the two charges are equal, or each is 10 per cent.

Miscellaneous.

(c) Ten per cent. for miscellaneous must include everything which has been unclassed. It has to be divided equally over all departments, and consequently 5 per cent. will be due to the trains and 5 to the so-called fixed charges of the line.

The *trains* portion will be divided equally between the *ton mile* charges and the *velocity* charges (for staff and repairs),

* Total traffic offering.

and the *fixed* charges portion will be divided in the same way between the maintenance, general, stores, and direction.

This will clearly give 1 per cent. to each department of the whole expenditure, and should cover all charges incident to the work done which are not included already as varying exactly either with weight, velocity, or time.

Such percentage for proportion of revenue for—

Per cent.

1 *Train Staff*, should include gratuities to guards or drivers, or passage to England, contingencies of all natures, &c.; Unclassified, Leave and sick allowance; repairs to drivers' and guards' quarters.

1 *Station Staff*—Gratuities for gardens to station-masters; watering trees; passages to Europe, &c., and all unclassified charges; for regulating the clocks, and all such establishment as does not belong to individual stations; leave and sick allowances; repairs to station buildings, repairs to telegraph.

1 *Repairs of Rolling Stock*—Provision of passages and leave and sick allowances, &c., to the workshop people, &c., and repairs to workshops.

1 *Rails* .... } These are chargeable with
1 *Sleepers and fastenings* } passages for platelayers; leave and sick allowances; gratuities for injury to men employed on maintenance; repair of tools and plant for maintenance; repair of gangmen's huts; level crossing, &c.; watchmen for stores.

2 *Fuel* is chargeable with labour in storing, apart from that required in loading engines at the time of working; all depreciation for loss of weight by exposure to air and sun, &c.; repairs to coal sheds.

1 *Administration* and heads of departments—All such charges as could be unforeseen; deputation to the agent or his officers; general advertisements; printing of the

Per cent.

annual or half-yearly reports and contingencies, and repair of the offices of all heads of departments.

1 *Stores* for the trains and stations, including cost of water for engines, are chargeable with loss on stores; repairs of tarpaulins, ropes, and petty charges; repairs of pumps at stations; repairs to stores buildings, telegraph stores.

1 *General charges* are the sum of the whole of the above small items. This head should itself contain an element of 1 per cent. for contingencies, such as compensation for loss of goods, &c., insurance; repairs to fences and level crossings.

10 Total.

As regards the repairs of the buildings included in the departmental classes, it is very evident that such charges will be very small when good material and construction has been provided in the first instance.

Special damage.

(*d*) No provision has been made in the expenditure for damage, the result of floods or other serious calamities, which will be the consequence of faulty design or insufficiency of the means to obtain stability, or in the case of collisions, &c., through overwork of the line, for which the capital does not represent the work to be done.

To include such contingencies would be tending towards a demonstration that the smallest amount of capital invested for a work was the best, and following the theory out to the end to show that it was better to invest no capital at all. We all know that an inadequate capital employed on absolute construction may be most remunerative very frequently, owing to a monoply enabling high rates to be charged; but it is always attended with more or less risk, and railways, if necessary to the traffic and proportioned to it, can afford to run no risk.

The construction expense must be perfectly adequate, and

the design unexceptional, and in all human possibility devoid of risk of failure.

Final proportion of Revenue expenditure for a line in full work.

35. The proportions of the items of the revenue expenditure has now been investigated for a line on a gauge suited to the traffic so as to keep it in full work.

They appear to be as follows, and should briefly include the annexed items of the revenue account:—

VARIABLE AS VELOCITY INVERSELY AND NUMBER OF STATIONS DIRECTLY.

Per cent.

10 *Station Staff*—Wages of all men at stations, including station-master, clerks, telegraph signallers, police, porters, pointsmen, greasemen. Semaphore men wherever placed.

VARIABLE AS VELOCITY INVERSELY AND NUMBER OF TRAINS DIRECTLY.

10 *Train Staff*—Wages of drivers, guards, and firemen, including overtime, and allowances of all sorts incident to the journeys performed; fuelling and cleaning engines and vehicles.

VARIABLE AS VELOCITY AND WEIGHT.

10 *Repairs of Rolling Stock*—All labour and materials used in the shops for renewals of wagons, carriages, and engines, repair of workshop, machinery, &c.; wages of carriage examiners, &c.

VARIABLE AS VELOCITY AND WEIGHT.

10 *Renewal of the Rails*—This includes only the cost of new rails, the carriage and laying included.

VARIABLE AS TIME DIRECTLY AND TON MILEAGE.

10 *Maintenance*—Includes renewal of sleepers, keys, ballast,* fastenings, packing, and keymen's expenses, and pay of all gangs and petty establishments.

* Not totally improved descriptions, which should have been provided in the first instance from capital.

VARIABLE AS TOTAL WEIGHT, 1 MILE.

20 *Fuel,* being the cost, including carriage of it, for use on the line up to the moment when it is required to be loaded on to the engines.

VARIABLE EXACTLY AS THE TRAFFIC AND INDIVIDUAL NUMBER AND WEIGHT OF TRAINS.

10 *Stores for Running Trains.*—2½ Locomotive, water, including wages of pumpers, and small store for pumps, &c. 2½ grease, oil, waste, for engines and vehicles.

(*a*) *Traffic* 2½ *Station stores,* for lights, water, fuel in waiting rooms, clothing of porters, police, miscellaneous, stationery, &c.

(*b*) 2½ *Train stores*—Clothing of guards, lighting trains, cooling carriages, miscellaneous stores in brakes, stationery.

CONSTANT CHARGES.

10 *Administration*—Agent, home expenses, traffic manager, locomotive superintendent, and all their offices; auditor, storekeeper, and their offices; medical department, police superintendent, law charges, rates and taxes, repairs to buildings under heads of departments.

VARIABLE WITH THE TRAFFIC AND WEIGHT OF TRAINS.

10 *Miscellaneous*—Gratuities, leave and sick allowances, compensation for injury or loss of goods, loss on
——
100 stores, insurance, repairs of a petty nature to pumps,
—— printing, advertising for general purposes, stationery and unclassified expenditure, contingencies, rent of land, &c.

The fixed charges in referring to different lines of unequal traffic will be made up of—

Station staff	10
Repairs of stock and rails due to the weather and time	10
Maintenance	10
Administration	10
Miscellaneous charges	10
	50
Train charges	50
	100

Comparison of proportion with those ascertained from past expenditure.

36. It does not follow that there will not be some variation when the quantity of traffic which has been carried is less than the full quantity for which the line was constructed; but it will be well to ascertain how far the proportions have been maintained in some lines of which we have some record and know the bearings.

It must be clearly understood also, that though the proportions above ascertained to exist are most possibly correct, they will not be absolutely maintained in any one half year, for the obvious reason that maintenance of both way and stock and all such charges are never made at the moment the dilapidation or expense has occurred, and with an alteration of the traffic the repairs of one period, for instance, will be accounted for, and contrasted with the repairs due to the dilapidation caused by the traffic or weather of another period; but taking an average of years or a wide extent of railway systems, it will be found that there is substantially little or no divergence from the proportions that have been ascertained, but what can be explained by the scale of the railway being disproportionate to the traffic it has carried.

Fuel.

(*a*) It appears that the fuel alone in proportion to whole working expense on the three Bombay Railways has been as shown below.

—	Miles now open.	Fuel Expense, Rupees.	Total Expense.	Proportion.
10 years, Sind Ry...	106	13,00,559	86,91,697	15·0 per cent.
9 years, G. I. P....	1,291	15,01,746	7,72,97,214	19·4 „
9½ years, B.B. & C.I.	312	39,65,180	2,24,08,325	17·4 „
	1,709	2,02,76,485	10,83,97,236	19·0 „

It will be seen from the table of data and charges on Indian lines at the end, that grease, oil, and other ton mile charges which belong to this head have averaged one-fourth of the charge for fuel, so that the whole proportion may have averaged 23·75.

The Sind and B. B. and C. I. Railways have both been subjected to heavy flood damages. All the lines have more or less had an insufficiency of traffic for the gauge, and both causes have resulted in a higher proportion of *maintenance*, casualty, and fixed charges, than would have otherwise occurred, which consequently makes the fuel and other ton mileage charges bear a less proportion to the whole than that determined by the inquiry. These causes will also affect *all* the *train* charge proportions more or less, as will be seen further on.

Train and Station Staff.

(*b*) Now as regards train and station staff, it may be observed that it is by no means easy to get at the average of a series of years, for the revenue accounts, if they could be obtained, would be found to have the items so mixed up that they could not be elucidated.

The new forms of revenue account remedy this evil to a great extent, and by taking the average of charges for *different lines* for a period of not less than one year, we may get a fair approximation.

From the revenue accounts available it appears that the following are the proportions of train and station staff.

Proportions of one year (1871).

——	G. I. P.	B. B & C. I.	Sind.	Madras.	Great Southern of India.	Average.
Train Staff	10·76	6·3	5·95	10·25	9·32	8·5
Station do.	8·71	10·61	8·63	9·49	8·83	9·25
	19·47	16·91	14·58	19·74	18·15	17·75

These variations between station and train staffs are what a line is liable to in any short period, and depend on the traffic of the season. The average comes for this particular season to 17·75 per cent. of the whole expenditure, or 8·875 for each class of establishment.

Rails and Rolling Stock.

(*c*) Next the repairs and renewals of the rolling stock and rails (3).

——	G. I. P.	B. B. & C. I.	Sind.	Madras.	Great Southern of India.	Average of first four Years.
Rolling Stock	15·64	12·24	14·00	12·26	10·96	13·54
P. W. Material	7·88	5·66	2·44	10·16	not known	6·54
	23·52	17·90	16·44	22·42	......	20·08

The average is 20·08 per cent. for both P. W. material and rolling stock.

The P. W. material includes all sleepers, keys, &c. It is much to be regretted that no revenue accounts show the expenditure on rails separately. It is very possible that most of the above material is entirely composed of sleepers, keys, &c., and since the deterioration of rails would be about equal, the figures may be adopted for want of more precise ones, as the rail proportions. Now these figures, when taken jointly, seem to confirm the assumed proportions, but taken separately to do no

such thing; but on consideration it will be evident that the proportions are liable to vary very greatly in a short period, and that independent of this, the rails cannot be expected to show generally such a large expenditure yet, for the lines having been opened only 10 or 12 years, and during that period never been worked up to above 70 per cent. of their power, no renewals to anything like the full extent of the depreciation can have been made. The actual wear of the rails is not ascertainable till they become unfit for further duty.

The proportions severally and unitedly must be higher than if the line were in full work, and the element of rail renewing claiming a larger share of the whole working.

But these proportions can only be reviewed over long spaces of time or large areas of country, and it will be seen further on, that the proportions are in a very large degree confirmatory of the correctness of the theoretical proportions.

The excessive wear of rolling stock seems to require some explanation. It may be that the maintenance of the road has not been so efficient as it should have been, and this is very probable when we look at the expenditure on the items other than rails since the lines have been open, and that the roadway is only now getting into fair order.* It is most probable that the high maintenance is somewhat the result of the scanty expenditure on good ballast and sleepers in the first instance. It will be seen that the rolling stock renewal for all Indian Railways in 1871 appears to be 8·9 per cent. We now come to *Maintenance other than for Rails.*

Maintenance other than Rails.

(*d*) It may not appear easy to arrive at any conclusions on this head; the following may be very near the mark:—

Mr. Barnett, the able Auditor of the G. I. P. Railway, has taken out the cost of the maintenance of the lines

* It proceeds in the case of the Sind and B. B. & C. I. Railways partly from having a very large excess stock for the traffic, so that reparis are going on for 'time,' while no corresponding expense is being incurred for working.

shown below, including rails, amongst much other valuable information.

Maintenance per mile of single track, including Engineers' salaries, &c., for half-year ending 30th June 1872.

G. I. P. Railway	832
East Indian Railway	602
Jubbulpore Line	457
B. B. & C. I. Railway	1,106
Madras	571
East Bengal	1,993
Oude, Rohilcund	379
Sind, Punjab, Delhi	404
Sind Section	463
	9)6,807
Average	756 for half year.
	2
Total	1,512 per single track mile per annum.

Now it may be said that the expenditure in a half year gives no idea of the maintenance. This is very true, but the chances are that by taking several lines the average will be a fair one, for some will be renewing extensive damage, others slight. In a wide area of country they are not likely to have all experienced the same floods or extensive renewals, though they will all be liable to such some time or another. It would have been perhaps more satisfactory to have had the whole charges for a complete year. However, such as the estimate is, we get Rs. 1,512 for the maintenance per track mile; add sidings one-tenth, giving total per mile of line Rs. 1,663. Mr. Juliand Danvers, in one of his reports, gives the cost of the lines in India, and it is gathered from them that the average cost of the principal lines has been £16,885.

According to what has been said previously, the working charges should be equal to the interest on the capital, £845; also

20 per cent. of this should be for maintenance of permanent way, (*i.e.*, 10 per cent. for rails and 10 per cent. for other parts) £169.

The maintenance based on the average of the lines quoted is Rs. 1,663 or about £166 a mile.

These figures are in remarkable agreement with 20 per cent. of the working charge due to a line costing as much as above stated, and with 5 per cent. of the first cost of the rails (I) and sleepers, fastenings and ballast (II), and as each of these two classes of material cost the same, and form each of them 10 per cent. of the first cost of a railway (Art. 35), the inference to be drawn, if the figures referred only to the permanent way, would be that each will be represented by 10 per cent. of the working expenses.

This omits all the small charges for station repairs, &c., but they are a very small proportion of the whole, and will be treated of in 'miscellaneous.' Extraordinary restorations are of course not admissible.

As such charges, however, have certainly been included in maintenance, besides others being actual improvements, the coincidence of the maintenance figures with those determined by the inquiry must apparently be due to the inclusion of such extra charges to an amount nearly equal to that which would have been due for rails, had their deterioration been fully represented in the accounts.

(*e*) It is not easy to take out the charges for *direction, general, &c.*, from the different accounts; but inasmuch as we have seen that there are good grounds for assuming that all the rest of the items which we have been able to class with various constants or variables should make up 70 per cent. of the whole charges, it follows that those which remain and which should certainly vary as the total quantity of traffic should be represented by the remaining 30 per cent.

(*f*) As regards the composition of this class of charges, Art. 32 indicates that 5 per cent. will refer to the water, grease, and oil used on the trains.

The charges under Art. 35 (*a*) (*b*) for the traffic, stores, and contingencies of trains and stations appear to belong to a class similar to that used for the locomotive department alone, and might be expected to have the same proportion as the other charges for any train, viz.—

		Variable.
Train Stores	1	No. of trains.
Station do.	1	No. of stations.
	2	
Locomotive Train Stores	2	Ton mileage.
	4	

And since the latter are 5 per cent. of the whole line, it would lead to the conclusion that the others must be 2½ each, and this appears to be the proportion in practice.

Also the locomotive charge of 5 per cent. for water, grease, and oil for vehicles and engines seems divisable into two parts; for the pumps and wells are all at stations, while the grease, oil, &c., is used on the trains, and they might be expected to be in the same proportion as train and station other expenses, or each half. The revenue accounts also appear to bear this out. The fact that the united train staff charges should equal the station charges for staff, and that the latter is made up of charges for number of trains and for velocity in equal proportions, shows that for the maximum effect, the *stations* should be as far apart as will produce a charge per mile of line for station staff equal to the train staff charge per mile at the economical velocity. Thus if the velocity per hour should be 15 miles, the stations should be that distance apart, which would give the least number of them with greatest distance apart; thus the station and train charges are clearly related whatever the gauge, and in proportion to the velocity; it is natural to expect that all the charges of whatever nature incurred through the direct medium of the staff of trains and stations, will vary as those staffs themselves, for every train and the whole number of trains,

and that consequently the whole expense of the trains and stations will be equal, and it is highly probable that this will always be found to be the case.

37. To revert to Art. 24 (*g*) and see now how the train proportions enable rates for any train load to be calculated. Take an assumed speed in each case of goods and passengers and see the result—say at 11 miles for a goods train and 21 miles for a passenger train—the cost per mile for the wages of the train staff is 33·33 and 17 pies per mile.* The proportions of the charges for a train are—

Use of the Train proportions of expenditure.

	Actual. 11 miles.	Proportion.	Actual. 21 miles.
Train Staff......	33·33	1	17
Station ,, ...	33·33	1	17
	66·66	2	34
Repairs, &c. ...	66·66	2	34
	133·32	4	68
Fuel, &c. ...	133·32	4	68
	266·64	8	136
Agency, &c....	266·64	8	136
Total cost ...	533·28	16	272

The economical limit of cost of the trains is 533·28 and 272· pies per mile.

Next, to find the weight of each train we must know the price and effect of a pound of fuel. For a level line like the B. B. and C. I. Railway one-seventh of a pound will be expended on the average on hauling one ton a mile.†

The quantity is capable of being estimated for a given line of which the section is available, and the character of the rolling

* Cost per hour for the wages divided by number of miles run.

† Not certified correct, there having been no sufficiently accurate records kept of all ton mileage.

8 R

stock known. It would be too great a divergence from the subject of this paper to enter into the calculation.

Taking the above result of the working of the B. B. and C. I. Railway, nearly level throughout, as correct for lines of that class, let us see the weight that should be hauled in the trains, the cost of which we have found at 11 miles and 21 miles an hour :—

The cost of fuel, grease, water, &c., is in each case—

	Pies.		Pies.
	132·32	and	68·0
Deduct—Grease, water, &c., 20 per cent.	26·46	„	13·6
	105·86	for fuel only	54·4
The cost of a pound of fuel is 2 pies. This gives 52·93 lbs. and 27·2 lbs. per train, over one mile, respectively	52·93		27·2
Each pound moves 7 tons	7		7
	Tons.		Tons.
one mile, which gives for the whole weight of the two trains.	370	and	190
Deduct—Engines, brakes, &c.	53		54
Total weight of vehicles and loads.	317		136
Or at 10 tons for the weight of a loaded goods and 8 tons for a passenger vehicle, about	32	vehicles and	17

(*a*) It is necessary to explain how it is that the constant of 7 tons moved by 1 pound of fuel applies to the two velocities, or indeed to any velocity in economically regulated train loads.

Quantity of Fuel per ton, a constant.

An illustration will perhaps show this in the simplest manner.

There are two things which the fuel has to be applied to, viz., overcoming the weight of the train, and the wind resistance.

Pambour gives 70 square feet for an engine and tender, *plus* as many times 10 feet as there are vehicles in the train for the *whole surface* for direct resistance of the air.†

Well, then, seven carriages work the same amount of air resistance as the engine and tender.

The surface of a passenger train of 14 vehicles with engine and tender will therefore be for air resistance ...... 70 × 3

For a *goods* train, 35 vehicles .... 70 × 6

Take the velocity of *goods* at half of *passengers*. Then resistance in *goods* is one-fourth for *velocity*, but the *surface* is double; therefore the resistance of air will be half in the *goods* train.

The weight of the trains will be—

		Passenger.		Goods.	
Engine, &c.		46·5		46·5	
Brake..........................		8·0		8·0	
Vehicles	14 × 8·5* =	119·0	35 × 9* =	375·0	* average with load.
		173·0		369·0	

It will be seen that the weight of the goods is about double that of the passenger, and that the surface resistance is about half, so that the compound ratio of the two will be constant.‡

† Pambour's rule was for the 4′ 8½″ gauge.

‡ If a train of the same weight and length travel double as fast, the portion of pressure due to wind resistance would vary as the velocity squared; but as the time occupied in the journey would be as the velocity inversely, the wind resistance would be as the velocity simply. The stock and rail repairs for the train would also vary as the velocity (Art. 21 *f g*).

The repairs would be equalised by saving in train-staff while the train was running, but fuel would be exceeded for the extra wind resistance, so that it would cost more for the train on the whole even while running: but if the expense saved by quicker running in the train staff item was lost by delays at crossing stations, which would occur in a line altogether over-worked, the increased expense would be so much more in all the items. A line therefore, working with greater loads, velocities, and number of trains than the economical limit for which it was constructed, will simply be substituting working

This is the same thing as stating that as the velocity increases the weight must be diminished, and *vice versâ*.

It is perfectly true that the consumption of fuel and total expense of the train will vary for every incline and with every velocity and direction of the wind; but it is impracticable, even if it were desirable, to alter the rates for every contingency in the particular train.

The rates will have to be based on the average consumption of the whole line. This average can be predicted with accuracy or ascertained experimentally, or by register of ton mileage, and when once determined, will apply to the whole traffic.

It may be as well here to remind the reader that for a traffic carried on for a whole year in both directions the wind will affect trains on the whole equally; for as it will be against the trains coming in one direction it will be favourable to those going in the other, and so on, with every degree of variation in the direction of the wind.*

Also as regards the inclines, much of the force expended in going up the inclines is equalised by the force of gravity propelling the trains down the inclines, and as trains are going both ways at all times, the slight excess of fall in one direction is made up by the corresponding rise from the other direction in another train.

It is easy to see that a large deduction has to be made on

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expenses for capital interest payments, and carry not one bit the cheaper or earn more net profit. This after all is quite natural; there can only be one maximum effect for a given capital.

If advantage is to be got from over-work, the more thrust on a line the better, and we should not stick at double or treble the proper quantity; if we could get 20 times the work out of our capital borrowed at 5 per cent. would it be no advantage? Since capital is after all only a reservoir of force, it seems much more likely that we should be using it all up in one year, and thus making it simply a working expense.

* Side wind causes a constantly increased load or weight of trains, but it will apply to all trains of equal length equally: the quantity of fuel per ton mile will be increased for it, however, without any corresponding decrease elsewhere as in the case of head wind.

account of the fuel saved in going down inclines, though an excess occurs on the whole through the introduction of heavy gradients, and especially where the brakes have to be applied, for in that case the additional fuel expended in going up the inclines is so much more in excess of that saved in coming down again.

CAPITAL COST.

38. (*a*) We have now attempted to show how to get at the principal proportions of the expense for working a line and a train. It will be better, before proceeding any further, to inquire into the cost of the various parts of the line which will certainly have some relation to one another. The works necessary to make a railway are—

Works composing a Railway.

Embankments,	Fencing,
Bridges,	Ballast,
Drains and Culverts,	Sleepers,
Stations and Buildings,	Fixings of Rails,
Staff quarters,	Rails, and
Telegraph,	Rolling Stock.

The above comprise nearly the whole of the principal works, and the cost of them constitutes the capital of the line.

The maintenance of these works is a revenue charge which amounts to 20 per cent. for the rolling stock and rails as shown before, and the remainder 10 per cent. provides for all the sleepers, ballast, &c., directly affected by the work done.

(*b*) Now there are two elements at work tending to destroy the railway. One is time and the weather, the other is wear and tear. It is evident that time and weather—a constant destroyer for most material—applies to every item on the capital account, whereas the only items affected also by the ton mileage wear and tear are the rails (1), rolling stock (2), sleepers, ballast, &c. (3), requiring constant adjusting for the effect of momentum of trains; hence the necessity for estimating the repairs and renewals of the different works separately.

Elements tending to destroy the materials.

It has been already shown that the repairs of rolling stock and rails should be 20 per cent. of the whole, and each should be half, thus each will be 10 per cent.

Quantity of material.

(c) It would be absurd to lay in such a quantity of rolling stock or rails as to have the deterioration going on for a time, while none was going on for ton mileage. Also if a material will not last longer than a time required for the work to be done, it will constantly require replacing as fast as the work is performed:* there must be a point between these two extremes when the proper amount of capital has been spent in producing an article which will last a proper time with the work it has to perform.

It is not sufficient to produce an article, such as a rail, which requires annual renewal. Capital is to be spent in order to *prolong* the life with a given work, the object being to make a capital investment of a yearly working expense. (Art. 11).

Durability desirable.

(d) There should be a deterioration corresponding to the work done and no more. The work to be done is to be so proportioned to the capital that the interest is to equal the working expenses.

The working expenses due to the rails and rolling stock are the cost of their renewal. The renewal should therefore be at the rate at which the capital was borrowed. If at 5 per cent., the *money value* of the whole of the rails and rolling stock must evidently be assigned to represent a duty of 20 years' work, and it is only desirable to spend so much on their total construction as will ensure this.

Since the deterioration should be proportional to the capital, and the working expenses of the whole line are equal to the interest on the capital, of which 10 per cent. is due to rails and 10 per cent. is due to rolling stock, it seems indisputable that the capital expended on the two latter must also be 10 per cent. each of the capital.

* Becoming in effect a 'working expense.'

Proportion of Rolling Stock.

(e) The actual proportions for Indian Railways were a year or two ago—

East Indian	11
G. I. P.	12
Madras	11
B. B. and C. I.	14
Great Southern	9
East Bengal	10
S. P. D.	12

The above includes machinery in workshops, which accounts for some of the excess. Some of the railways show also an excess which may be due to a really larger stock than necessary, all bearing interest.

All the lines have been supplied with the maximum proportion of rolling stock, and the B. B. and C. I. and S. P. D. have notoriously more wagons than required.

Weight of Rails.

(f) Next, to test the figures for rails approximately. For this purpose take the G. I. P. Railway. The cost of the *rails* should not exceed one-tenth the whole capital cost, or Rs. 17,300 per mile. The sidings form 10 per cent. of the whole length of single track.

	Rupees	17,300
Deduct this	„	1,730
Total rails on main line ...	Rs.	15,570

The iron rails have cost as under:—

	£
Rails per ton in Bombay, freight included	13
Carriage, average 240 miles (average for G. I. P.).	1
Laying	½
Total per ton	£ 14½

This price gives as nearly as possible 100 tons of main line rails per mile.

$$\frac{100 \text{ tons} \times 2{,}240 \text{ lbs.}}{1760 \text{ yds.} \times 2 \text{ rails.}} = 64 \text{ lbs. to the yard,}$$

which is remarkably near the actual weight, 68 lbs., considering the carriage data can hardly be perfectly accurately known, or assumed.

The Bhore Ghaut has cost about £69,000 a mile, or four times the cost of the main line; according to the above proportions the weight of iron per yard in use in rails should be 256 lbs.; this could be divided (and is so), into two lines having rails of 128 lbs., or steel rails, supposing the price to be half as much again as for iron of 85 lbs. to the yard.

Ghaut Rails.

As a fact, the old iron 85 lbs. rails are wearing out with great rapidity, their life being hardly four years on the falling gradients, and are being replaced by steel rails of 85 lbs. to the yard. They were evidently not heavy enough. Bessimer steel rails are being sent out now at a cost of 16 guineas against 12 guineas for iron. There can be no question of the desirability of using these on parts of the line subject to the heavier traffic, descending inclines, &c.

Since the traffic over the ghauts is the same as on the lines adjacent, it shows that the weight of rail depends on the *work* to be done on the gradients, and that 'traffic' and 'work' are not terms to be used indiscriminately in speaking of railway performances.

It will also be seen in Art. 46*f* that on English railways the 75 and 82 lbs. rails, though much heavier than due to the 4′8½″ gauge, are found to have only half the life they should have. The capitals of the lines however are double that due to the gauge, and the work done on them is about the same. So the proportions are still correct even in those instances.

What has been said regarding the capital and the proportion of the repairs consequent on every investment in machinery will now be applied to other materials.

(*g*) It will be evident that we do not require to invest any more capital than that of which the interest will equal the repairs. So for sleepers a life of 20 years with money at 5 per cent. will be

Sleepers.

sufficient, &c. &c., but if for purposes which we cannot attain without, we are obliged to invest an excessive capital in a more durable material, so long as we find the repairs are diminished for the work done, we are getting a corresponding advantage.

Other materials.

(*h*) Now, it happens that in order to make our railway there must be an embankment, bridges, &c., &c., all of which will last much more than 20 years without entirely renewing. There seems almost to be no limit to the life of an embankment and bridge, &c. The heart of a well consolidated embankment hardly undergoes any material damage from the weather, but it must be well known that occasionally 'a higher flood than any on record' will sweep away a mile or two of embankment and several bridges, the renewal of which is generally made a charge to revenue. It may be thought that iron pot sleepers are practically indestructible; this is far from the case. A mile of them has been known to be smashed by a vehicle off the line, &c., &c.

Now the above damages are such as may be classed as occurring with accidental causes. They don't often occur unless there has been faulty design or insufficiency of well considered capital expenditure in some shape or another. Their repair will be as much a contingency as the loss of a bale of piece goods, and their general effect on the proportion of maintenance charges hitherto, may be gathered from the fact that the whole maintenance, including various improvements, the repairs of buildings, &c., and all permanent way material,* has hardly ever exceeded on a wide area or large number of lines the usual 20 per cent. (Art. 36 *d*.)

The coincidence of the repairs with this proportion has already been shown, but another example which has just turned up in the *Government Gazette* may be quoted. The maintenance for the two half-years ending December 1871 and June 1872, is shown to have cost Rs. 1,703 a mile open, includ-

* Not many rails perhaps.

ing all charges against permanent way renewal fund, &c., deduct the proportion 50 per cent. due to rails, this leaves Rs. 850 per mile. The average cost of all the railways, as before stated, has been £16,885, giving for rails £844, and there remains £844 for the cost of the other parts of the line, giving the repairs at 10 per cent., as near as possible, the whole maintenance on this sum being 20 per cent. of working expenses, is as near 1 per cent. as possible on the whole capital.

It is evident that 1 per cent. of the original cost applies to the whole of the capital spent on material which simply deteriorates from time and weather, but it will not apply to all materials. The sleepers may require renewal five times in one hundred years, nevertheless the expense will be no more if five times the original capital be spent on them provided the life can be prolonged to 100 years. It has been shown that the *smallest* amount of capital and working expenses will be when the interest on the former equals the latter. It is an object to attain therefore a proper life for every material, but if we cannot do without a material having greater life, it depends on our power of getting work out of it, whether we are justified in the expense or not.

The life is simply the *time* it will last for a given amount of *work*.

From what has been said it is plain that if we can borrow money cheaper, the charge for interest will be less, and it will be better to spend more of it in producing, for instance, rails which will last longer, so that reduced money interest should mean lengthened life of the material. If at four per cent. the life should be 25, and at three, 33 years.

Illustration of Capital expenditure on bridges, &c., and probable deterioration.

(*i*) As an illustration of the relative value of lives of bridges or river crossings, suppose the sleepers are laid over the river bed, they will be washed away annually and the cost of repairs, &c., &c., to that river crossing will have to be recovered from the traffic, being the amount of labour and material used, the charge will be a working expense.

It is clear that so long as the traffic remains the same we may invest as much capital in a bridge in place of the temporary crossing as would give an interest equal to the cost of the repairs less repairs to the new bridge. If money is at 5 per cent., this means 20 times the amount, if at 4, 25 times the amount; up to these limits we shall. not be paying more for the river crossing than we paid before. We would simply substitute a capital interest payment for a revenue one, but inasmuch as we saw before that the structures depend in magnitude on the quantity of work to be expected from them, we should be justified in spending double the above amounts for double the traffic, and 5 times the amount for 5 times the traffic, and so on.

But as no more work can be got out of the material for its durability than the design of the line provides for, an excess total duty can only be got out of it in course of *time*, and this means that the life to be ensured should be as the amount of work directly at least.

From this it will be seen how it is that the maintenance other than permanent way is so small; for we know that good walls and masonry will last for centuries, and earth in solid masses can undergo little change, &c. It is most probable that the mass of the above 70 per cent. in railway works will not deteriorate ½ per cent., and this long life in the principal works soon compensates the loss of a few bridges, &c., and if any single work of a large system last, say, 50 years, it may be said to have done a fair duty.

It will be evident from this that in an experimental line where the traffic to be expected is unknown and the rivers are shallow and seldom in flood, it will often be cheaper to renew the river crossing annually than build an expensive bridge, till it is clearly ascertained that there will be traffic*

* The limit evidently lies between 1 train and 12 a day, or the equivalent. But it must be remembered that the expense of a diversion is not only the annual reconstruction, but there is increased working in every part of the train expense, such as loss of time, extra fuel, wear of rails and engines, &c., for the inclines.

enough to earn the interest on the capital required for the bridge.

Also since the life is regulated by the rate of interest and the magnitude of the investment by the amount of work to be done, it does not seem absolutely necessary to invest more capital than will ensure any one bridge standing from 50 to 100 years, for with a full amount of traffic over the line it may have then possibly paid itself off. Excessive expenditure to provide for the vastest floods possible does not seem called for; but, on the other hand, safety must be ensured by an adequate provision of water and headway for any highest floods known or ascertainable by exact inquiry, and the class of work cannot be too good within reasonable limits for railway work of all kinds, where capital is to be got cheaply.

SCALE OF CONSTRUCTION.

39. Having now shown some of the proportions of railways for the work to be done, which will apply to every sized undertaking practicable, let us proceed to see the relation of railways of different sizes to one another.

General requisites.

(*a*) Economical construction of a railway is one providing for constant work, and for the vehicles to contain as much as possible with as narrow a gauge as can be made, giving the greatest amount of stability and greatest velocity *for the work to be done.* Here are things to be all equally considered.

The roadway is required to be narrow to make the cost of construction of the line as little as possible, and cost of tunnels, &c., least; but the carrying capacity of the rolling stock requires that its transverse section should be as broad as possible to take as much traffic as it can. Here are two things opposed to one another. For a line to take traffic of nine times the amount of another line it would be absurd to make either the road and tunnels, or the carriages and wagons nine times the size by widening them only. In regard to the road, it will be widened somewhat, and the tunnels will be widened and heightened,

and in regard to the wagons they will be widened, lengthened, and heightened, and they will travel faster.

Form of Vehicles.

(*b*) It is clear that having fixed on the best form and proportions of the parts of a railway there can be no departure from them without some disadvantage, although it is quite possible to make railways of different sizes without doing this.

The section of a passenger or covered goods vehicle which will contain most, with the wheels nearest to one another, but still giving the greatest stability, is evidently when the body of the carriage is a square when seen in transverse section and the wheels are under the vertical sides of the carriage or wagon, for the square is the figure whose centre of gravity will be lowest for the same area; and although it might be put lower in an oblong of the same area by projecting the vehicle body over the wheels, you thereby infringe on the requirement of stability by the leverage of the overhanging part, and cause the construction of the way to cost more to allow of the space for the passing of trains or passage through tunnels and over bridges.

There seems to be no other economical section for the wagon bodies than that now pointed out. A divergence to obtain an advantage in one direction is inevitably met by a disadvantage resulting in some other.

By the wheels being closer together for the same body, stability is lessened and repairs are increased; by extending the wheels outside the body the stability is increased at the expense of the way which must be wider. By projecting the body beyond the wheels the width of way must be increased for the same quantity of traffic 'Q,' so that there is all the disadvantage of the expense of a broader gauge without the stability or power of speed; either repairs will be increased or velocity must be diminished.

In fact there appears no way out of it; there can be only one principal form for the section of the way and wagons or carriages, and that is, the stable one that reaches as near the description given as possible. The body may be placed

as low as it is possible to get it with these requirements first attained.

In practice, on the Indian 5½ feet gauge the wheels are just inside the wagon frame, which is the nearest they can be put to the vertical line through the sides of the carriages allowing the floor of the vehicle to be as low as possible, without touching the wheels.

As regards the length of the vehicles, it would appear that it is unlimited, provided it is sufficient for the wheels to be a respectable distance apart to prevent waggling; but for ordinary vehicles it is in the first place no advantage to have them of other than a handy size; moreover, the rails will only bear a certain weight per wheel, and for four-wheeled vehicles, if the floor area is to represent the weight to be accommodated, there must be a limit.* A convenient limit appears to be when the wagons are in length about twice the breadth. This will allow the wheel base or distance between the two pairs of wheels to be twice the gauge of the particular line, which will give a maximum amount of steadiness combined with least weight per wheel and least oscillation. Now as these laws apply, whatever the gauge, it appears that every part of the rolling stock requires to be made in the same proportion whatever the gauge adopted.† The covered wagons, to take a particular type of wagon, will be double cubes having a direct relation to the gauge, and all other wagons with their loads the same.

The *wagons* of different gauges, therefore, will vary in total capacity as the *cube* of the gauge; in floor area as the square of

* American cars are long girders supported on bogie trucks with many pairs of wheels. The cost per square foot of such construction to be equally strong must increase with the span; the repairs will be in inverse ratio to the original strength.

† Since the total cost of all the vehicles of a railway forms a constant proportion of the capital, the number of vehicles and size of each will be in inverse ratio, which shows that there is no necessity to increase the size above that indicated, for the number of them would be diminished as the size of each was increased, the total wagon capacity remaining the same.

the gauge. The *transverse area* of the wagons will be as the *square* of the gauge.

The only goods that can be piled up very high are light ones, such as cotton and wool, hay, &c., and in such cases it is often impossible to get a very large weight into the wagon; but in the case of other goods they cannot be piled up higher than the wheel weight will permit.

(c) Now there are two ways of looking at the proportion of vehicle weight to load. They are, that the vehicle shall be proportioned to the *weight* it is to carry, and that it shall be proportioned to the *work* it has to do, and the two things are widely different. If the velocity on different gauges is the same, the vehicles may be compared by the weights to be carried, and in such a case the weight of the vehicle has only to be as the square of the gauge in order for it to be in equal ratio to the area of the floor, and consequently the capacity. But since different gauges afford *velocities* in proportion to them, a gauge for, say, double the *work* would have vehicles only as $\sqrt{2}$ or 1·4 times as large, and travel 1·4 times as fast. Here the load in the vehicles would not be double, but the work done by the vehicle, including its own weight over 1·4 times the distance in the same time, would be double, and in order for it to be proportioned to the total *work* performed, would therefore still have to be in weight as the square of the gauge.

The cost of the vehicles being therefore as the *work* to be performed, will be as the square of the gauge in all similar constructions, and since the surface of them must be as the square of the gauge, but the content is to be as the gauge only, the thicknesses of the scantlings would have to be as the gauge itself to give the necessary weight and strength.*

(*d*) Regarding the engines and their value for the gauge.

It appears that the engines must be capable of drawing the traffic at the proper velocity for the line.

* Which seems to explain the apparently greater proportion of dead weight of individual vehicles in broader gauges.

The *power of draught* of the engine depends on its *weight*, the *velocity* on its power of *vaporising* the water with proper rapidity.

The velocity increases for every larger quantity of traffic a line is designed to accommodate; so does the *train weight* in the same proportion. The engine for an increasing quantity of traffic must therefore increase in weight and vaporising power as the traffic directly.

The great body of the weight of the engine, in order to give proper stability, must in all cases be within the wheels as for vehicles; centre of gravity must be low.

The best form will evidently be when the boiler is the same diameter as the gauge, for then it will be largest, while there will be no projection over the wheels causing instability; a boiler of such a diameter placed as low as possible to the wheels will be the best in point of stability and capacity, when seen in section, as here described. To augment the power of the engine we have evidently the element of length to work upon, to some extent, without altering the section.

The weight of the boiler depends on the diameter, length, and thickness of the plates; engines of different weights, for various gauges, may certainly be taken to vary in weight as the weight of the boiler, for all things must be made in proportion thereto.

The pressure tending to burst the boiler varies as the diameter, but for the increased pressure resulting from the increased diameter there must be a corresponding increase in the thickness of the plates. The sectional area of the iron boiler plate will consequently vary as the square of the gauge. If a proportionate length of the boiler will give the proper vaporisation, it is evident the weight and cost will then be as the square of the gauge.

As the vaporising area of the engine varies as the length of the tubes and area of fire-box, and the diameter and length of the former and side of the latter must be as the gauge, the total vaporising area will be as the square of the gauge; there

can consequently be no difficulty in getting sufficient steam for the velocity for the gauge.

Applying this to a single case of the G. I. P. and Dubhoe Railway engines, 5′ 6″ and 2′ 6″ gauge respectively, the Dubhoe engines cost £683, and the gauges are as 1 to 2·22—the square of the latter is 4·941. The cost should therefore be 4·941 × 683 = £3,374, which is almost exactly the average cost of the G. I. P. engines.

The price of similar engines for other gauges would accordingly appear to be for India at the same rate.

	£
4′ 8½″	2,331
3′ 6″	1,332
3′ 3″	1,200

Dead Weight.

(e) For stock to be equally stable the capacity will be as the square of the gauge.

The line requires that the work to be done shall be essentially as the square of the gauge, and that dead weight for the *whole* traffic should be always the same.

Now take a similar vehicle on a smaller gauge compared to one on a larger. Since its capacity is as the square of the gauge, the weight of the vehicle must be reduced as the square of the gauge for the *same velocity*, or its area for carrying capacity must be increased. The latter for double the gauge may be effected by making the wagon body half as broad again and half as long again, the same quantity of material being used. The former is at once easily effected by constructing the vehicles of exactly similar pattern, but keeping the thickness of the scantlings the same, and the weight must then vary as the surface—the whole weight will be as the square of the gauge.

But now introduce the velocity, which should be proportioned to the gauge. This element enables us to do work in direct proportion to it.

The reduced velocity for the above modified vehicles for the same total of vehicle and load, renders it quite unnecessary to preserve the same weight of vehicle. It may be reduced in proportion to the velocity. This reduction, however, produces

an exactly similar diminution of paying work in the same time.

The same amount of paying work could only be done in the same time by an increase in the total number of vehicles travelling on the road at the same time inversely proportional to the velocity.

This shows that the individual proportions of vehicles to loads statically considered will be directly as the gauge and not constant, but dynamically considered with regard to the work performed in the same time the proportion will be constant.

If we could not reduce the proportion of paying to dead weight in smaller gauges in individual vehicles and increase it in larger gauges, the velocity must be the same whatever gauge was adopted. But it comes to the same thing whether we reduce the velocity and increase the number of trains travelling on the road, at the same moment making them smaller, or keep to the same velocity for the same number of trains of greater weight as far as dead weights are concerned; but as far as the general design of the line is concerned, it will better be served when it gives employment to the whole staff for the complete day, and if the traffic is small it can be taken in smaller loads at smaller velocities, affording an opportunity for making a smaller gauge sufficient for the work.

This may be rendered more clear perhaps by supposing it necessary to find a gauge that shall do twice the traffic—that is, convey double the paying weight over the same distance in the same time, say 15¾ miles in an hour. It might be done by trains taking double the weight at the same velocity, necessitating double the quantity of engines and vehicles, or double the number of trains of larger size at twice the velocity —either of these would be extremes, one case requiring excessive loads and the other double the width of the gauge.* The mean would be when the velocity and weight of traffic in trains was as $\sqrt{2} = 1{\cdot}4$; now as the train travels 1·4 times faster on the broader gauge and takes 1·4 times the load, the total work

* The velocity could not be doubled on the same gauge if maximum loads were already being conveyed.

per hour will be as $1{\cdot}4 \times 1{\cdot}4$ or 2. The work is taken to be done over the same distance; a single journey will therefore be done in $\frac{1}{1\cdot4}$ the time, or 43 minutes, instead of an hour. The number of trains that can be run in the same time will therefore be augmented as 1·4. The work represented by 2 in an *hour* is therefore done in 1·4 trains instead of 1. But since the stock of a line is a regular constant proportion of its capital, this shows that the same stock is used over 1·4 times the distance in the broader gauge in the *same time* with the same freight load, consequently it will be worn in that proportion, and must be 1·4 times as strong. Thus while the loads will be as 1·4, the weights of wagons should be as $1{\cdot}4 \times 1{\cdot}4$ or 2; and in this way the wagons would exactly be proportioned to the *work* when they vary in weight as the square of the gauge, although the proportion of dead weight statically considered would increase as the gauge directly.

The wear will be as the weight or velocity; while therefore the latter is constant the former will vary as the square of the gauge. Also since the velocity on different gauges should be as the gauge directly, the wear of similar rolling stock varying as the square of the gauge in weight will be constant.

Wear of Engines and Vehicles on the level.

40. (*a*) The wear of engines and wagons is incurred at the same velocity under all circumstances. The wear of engines per vehicle has to be divided over the whole number of vehicles required to carry the traffic 'Q.' It becomes a question therefore what number of engines should be used for the whole traffic, or in other words, how much weight should be drawn by each engine (or how many vehicles on the average should compose a train). For the same quantity of traffic 'Q' it is desirable to have as few trains as possible, of least cost each, and consequently maximum loads with least cost per vehicle for engine wear.

If a train consisted only of the engine it would be the smallest in cost, but as it would usually do no work that would be remunerative without a vehicle, the least cost when any were attached would be when there was only one: but the whole cost for the engine being charged to one vehicle would make

the charge for that vehicle very high. If another vehicle were added the cost for the engine per vehicle would be halved, while the cost for the train would only be slightly increased. There would be an advantage then evidently in increasing the load of a train as long as the cost per vehicle was reduced in a greater proportion than the whole cost of the train was increased, for then only would the number of engines employed on the whole of the vehicles to carry the traffic 'Q' be least.

It will be advisable to take an example, and let us suppose that the wear of the engine is one-thirtieth of that of a vehicle, then trains of increased numbers of vehicles will be as under:—

No. of Vehicles.	Engine.	Total Train Cost.	Cost per Vehicle.
1	30	31	31
2	30	32	16
3	30	33	10
4	30	34	$8\frac{1}{2}$
&c.	&c.	&c.	&c.
28	30	58	$2\frac{2}{28}$
29	30	59	$2\frac{1}{29}$
30	30	60	2
31	30	61	$1\frac{30}{31}$
32	30	62	$1\frac{30}{32}$
33	30	63	$1\frac{30}{33}$
&c.	&c.	&c.	&c.

It will be seen that the total cost of trains increases very slowly, while the cost of vehicles diminishes very rapidly, at first, and gradually less so till the train cost becomes double the cost of the engine, at which point the wear of the engine equals the wear of the vehicles.

After that, it appears that additional wagons simply result in reductions per vehicle in exactly the same ratio to the increase in number per train, so that the cost of trains and vehicles are both increased as the vehicles are added. There is clearly no advantage in increasing the maximum economical loads after the point is reached, where the vehicle cost is only diminished in exact proportion as the train expense is increased, for it requires the same power to move a load whether that power is employed

in one train of double the length or two trains each half the long one. The destruction to engines is in one case entirely caused to one engine, but in the other case the same amount is divided between two. The desideratum is not to carry the largest trains possible on any gauge, but to use the least amount of engine power for the whole traffic, and that will be when the whole cost per vehicle is least; the charges for the engine and wagon repairs which go to make up the whole deterioration will each be least when they are equal to one another.

(*b*) As far as repairs are concerned, therefore, the most economical train is when the repairs for the engine equal the repairs of the wagons. This must evidently be true for the whole number of trains and the whole traffic. Since the repairs should be equal, the capital (38 *d*) invested in each should be half the whole.

Wear of Permanent Way.

41. As regards the permanent way, it has already been shown (Art. 35) that the cost of the rails should be one-tenth of the whole capital.

(*a*) The cost of the rails and supports, consisting of sleepers, chairs, bolts, spikes, &c., makes up the whole cost of the permanent way. The cost of the former (rails) is fixed by the weight for the work to be done; but the section of the rails may be altered considerably for the same weight, and the strength of the rails for bearing the weights will be considerably augmented by the depth given to it. It is possible therefore to get some variation in the number of supports using the same quantity of material required, by an alteration of the section; in proportion, however, as the supports are far apart they must be increased in strength, as the weight to be borne is constant. Now taking the other side of the question, viz., the supports. In proportion as they are near together the rails may be reduced in section, and the section would be smallest when the sleepers were absolutely touching, so as to give continuous support. But the larger the quantity of wood used, the larger must be the deterioration for time. It then seems immaterial whether more is spent on one or the other, the sum of the two must be constant. This being the case, there is no reason to

spend more on one than on the other as far as the maintenance charge is concerned for the actual work performed for both to be a maximum. But as the rails require to be equal to the rolling stock, the best arrangement will be that which limits the quantity of material in the sleepers, &c., so as to give an equal wear with that for the rails.

Whatever distance apart they may be, they may, together with the chairs, spikes, &c., and everything depending on their *number*, be considered as the piers of a bridge of which the rail is the superstructure.

42. It is clear that the cost of the supports of a bridge should equal the cost of the superstructure; the cost of the superstructure will be inversely as the number of piers for the same load per foot, while the cost of the piers will increase as their number exactly for the same load. These two depending on the same variable (number of supports) and referring to the same constant load will both be least when they are equal.

All bridge spans should equal the cost of the supports. All supports of rails, such as sleepers, &c., depending on their number should equal the cost of the supports, *i.e.*, the rails.

The actual cost of G. I. P. Railway permanent way material in Bombay was—

For 1 *Mile, Single Line.*

——	No.	Rate.	Weight.	Cost.
		Rs.	Tons.	Rs.
Rails 24 feet	440	131	106·50	13,951
Chairs	3,080	57½	31·00	1,767
Fish-plates	880	130	4·80	624
Bolts, nuts	1,760	176¾	1·32	234
Spikes	6,160	185	2·74	408
Keys, wood.........	3,080	$\frac{50}{40}$ per 1,000	1·07	500
Sleepers	1,540	6 each	77·00	9,240
			225·00	26,724

The cost of the rails was	Rs.	13,951
Chairs, sleepers, &c.	„	12,773
	Rs.	26,724

To see how this appears in a mile of single railway open on the G. I. P. Railway (see Art. 38 *f*).

Rails.		*Sleepers, &c.*
13,951		12,773
1,395	Add sidings one-tenth	1,277
15,346		14,050
1,227	Add carriage 8 per cent.	1,124
16,573		15,174
727	Labour (balance)	2,126
17,300		17,300

The labour on *rails,* amounting to about 4½ per cent., tallies somewhat with ⅓ £ or £14 a ton for the cost. The labour on the sleepers, &c., is best expended in providing good ballast, which ordinarily will not cost more than about one rupee a cubic yard, if so much.

Stations.

43. Article 36 *f* points out that the charge for trains should equal the charge for stations in the working, in order to get the greatest effect. The number of trains at the economical velocity should also be equal to the number of stations in the day's work. The expenses of the trains have an item, *viz.,* the staff, equal to that of the stations; also the stores are equal. The only other charges are the repairs and maintenance of the stations and the repairs of the rolling stock. The former have sidings equal to 10 per cent. of the whole single line; these sidings all require the complement of rolling stock, which consequently must also be 10 per cent. of that for the whole line; the repairs of the station buildings will be a very small figure on the one side of the account, and the repairs due to the *trains,* owing to their velocity through stations being almost *nil,* and vehicles standing at sidings, will be very small on the other.

The wear of rails, though small at stations owing to the smaller velocity will, on the whole, not be diminished on that account, because the speed lost at stations necessitates greater speed on the main line, and though the rails and permanent way at stations will be worn less, those on other portions will be worn more than if the stoppages had not been necessary.

It appears then that not only the station staff but also the rails and rolling stock and maintenance of the way must form 10 per cent. of the charges for repairs due to the *stations.* Also when trains pull up to cross at stations, there is a delay to both trains while no useful work, *i.e.*, velocity, is going on, which adds to the train staff charges, most possibly not less than 10 per cent.; so that the working expenses seem to be due 10 per cent. entirely to stations, and hence it is inferred that their collective cost should equal the whole cost of trains, *i. e.*, the whole cost of the rolling stock, or 10 per cent. of the capital should equal the whole cost of the stations including sidings, signals, and every other capital charge not belonging to the main line or particular departments.

In a smaller gauge line the stations will be nearer together but they must cost less each. The number of trains per station may always be 12, but the work each train will do will be as the velocity and weight. In order to preserve the same cost of stations per mile with least number, their distance apart is increased in proportion to the velocity, while the expense of them varies as the square of the velocity, so that the absolute expense will be as the velocity simply.

It is not true of any one station or train when you depart from the uniform maximum velocity and load but of the whole number. The number of stations may be increased if the expense of them is decreased or the traffic and number of trains is increased, in which case they will maintain their relative proportions.*

---

* On English lines the stations bear nearly double the proportion to the rails apparently. This would be accounted for by the double work for the gauge.

The identity of trains with the distances of stations is lost in a mixed traffic, but it will be evident that the relation exists when we thiuk of local traffic in populous districts where the number of trains is great and the stations only two or three miles apart. Trains and stations are indispensable the one to the other, and a rupee spent on one is no use without a corresponding amount spent on the other.

(*a*) '*Engineering*' for February 7th, 1873, gives the comparative cost of construction of the Norwegian Railways on the 4′ 8½″ and 3′ 6″ gauges.

In each of the five examples given the stations are entered at—

7·82	Lilleström.
11·75	Hamar.
10·34	Throndhjem.
9·71	Drammen.
8·70	Christiania.
5) 48·32	
9·66	per cent. on the whole cost.

The rolling stock is also given in this interesting article—

11·97	Lilleström.
10·53	Hamar.
6·67	Throndhjem.
9·73	Drammen.
9·00	Christiania.
5) 47·90	
9·58	per cent.

The last is particularly instructive as showing that no more total stock value is used although the gauge is smaller in the last four railways than in the first, and the capacity of the stock greater.

The gross ton mileage per mile of line on the Drammen Ransford was 103,115,—train weight 65 tons,—therefore this equals 1,600 trains.

The wear of wagons and carriages is $2\frac{1}{2}$ per cent. on the capital cost of rolling stock in other lines and according to theory. In this one it is £11 on £433; $2\frac{1}{2}$ per cent. on the latter would be £10·7, which appears remarkably near.

Carriages and Wagons.

RATES.

44. (*a*) To find now the economical velocity for a line costing £17,000, or say Rs. 1,70,000 a mile on the Bombay side.

Velocity.

The actual cost of the staff of a train for one hour, including all allowances, is 1·91 rupees = 366·72 pies.* The working expenses of the line should be 8,500 Rs. per annum, or 23·3 a day, or 1·94 Rs. an hour; of this $\frac{1}{10}$th will be station staff as shown before (Art. 24 *g*); the cost is therefore 23·296 pies per hour.

The train staff costs 366·72 per hour, so the distance travelled must be

$$\frac{366{\cdot}72}{23{\cdot}296}, \text{ or } 15{\cdot}74 \text{ miles.}$$

(*b*) To find the cost of haulage of a ton a mile from the whole working.

Ton Mile Expense.

The interest or working expense should be Rs. 8,500 per annum, $\frac{1}{5}$th of which will be for *fuel* only, or Rs. 1,700 = 163,200 pounds of fuel at 2 pies per pound, and at 7 tons hauled over a level mile for a pound of fuel, this gives 1,143,400 tons for the duty of the mile of line per annum:

$$\frac{8{,}500 \times 192}{1{,}143{,}400} = 1{\cdot}428 \text{ pies per ton mile for the whole expense.}$$

Daily work.

No. of trains 12, at 261 tons each, or the equivalent = 3,133 tons daily.

Proportions of ton mile expense.

According to Art. 35 the figures for gross ton mileage will be made up as follows:—

---

* See tables at end.

1.	Train Staff		·1428
2.	Station do.		·1428
3.	Repairs to Stock—		
	Vehicles	·0714	
	Engines	·0714	
			·1428
4.	Rails		·1428
5.	Sleepers, fastenings, and ballast		·1428
6.	Stores—		
	Locomotive—		
	Water	·0357	
	Grease, oil	·0357	
	Traffic—		
	Trains	·0357	
	Stations	·0357	
			·1428
7.	Administration		·1428
8 & 9.	Fuel		·2856
10.	Miscellaneous		·1428
		Total	1·428

(*c*) To find the average rate of carriage for goods and passengers.

Goods.

At $15\frac{3}{4}$ miles an hour the maximum velocity for the greatest load for the 5′ 6″ (see Art. 24 *g*):—

Train staff costing 1·91 Rs. per hour, would be—

	23·3	pies per mile.
	4	
Total...	93·2	Staff and repairs.
	93·2	Fuel, grease, oil and water.
	186·4	Total train cost (net).
	186·4	Fixed charges.
	372·8	Total cost.

Fuel, grease, water, oil (above). 93·2 pies.
Deduct $\frac{1}{5}$th for all except fuel ... 18·6

Fuel costs 2 pies per pound ...... 74·6

Quantity per train mile............ 37·3 pounds.
Tons over 1 mile per pound fuel... 7* B.B. & C.I. Railway.

261 tons.

261 tons costing 372·8 pies = 1·428 pies per ton gross, which is the same as that given by the last method (Art. *b*).

To find the rates chargeable—

Take gross weight ...... 261 tons.
Deduct—Engine, tender,
brake 53

Weight of vehicles and loads 208 tons = 25, at 8·35† tons each with freight; 40 per cent. is the average freight, see Art. 44 (*e*).

This gives 82·84 tons of freight,
costing 186·24 pies, giving............ 2·21 pies per ton.
Add—Agency general, &c. &c.... 2·21

Total cost ...... 4·42
Add—Interest on capital. 4·42

Total... 8·84 pies per ton one mile.

This supposes the freight to fill the vehicles each way, but as they are hardly ever equal both ways, this has to be taken into account. If they were always in one direction, doubling the rates would evidently more than recoup the double expense;

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* Chicago Pittsberg Railway gives 41·7 miles × 262 ton trains ÷ 2,000 lbs. coal = 5·467 tons one mile per lb. The gradients are heavy.

† 5 Tons for the wagon :

Proportion of freight $\frac{82·84}{25}$ = 3·35 tons per vehicle.

but if they were equally divided for the half-year and all one way for the other half, the rate need be only half as much again instead of double.

(*d*) Without accurate statistics showing the extent of the traffic, the lowest rate, the knowledge of which is of such immense importance, cannot be fixed; but in the absence of such statistics a maximum may be taken for an example, *i. e.*, when the traffic is all one way; the greatest benefit would then arise from dividing the loss from the inequality equally between the carrier and the consumer. The rates being thus half as much again on this account, would be 8·84 + 4·42, or 13·26 pies per ton per mile. This will sufficiently answer the purpose of illustration, and is somewhat near the prevailing rates.

A rate of 13·26 pies, representing the actual net cost at 6·63 with gross carriage cost at 1·428, Art. (*b*), would give paying load to gross .... $\frac{6·63}{1·428} =$ 1 to 4·68

But in Sind it is	1 to 3·0
B. B. and C. I. Railway	1 to 3·2
G. I. P. Railway	1 to 3·6
	3) 9·8
Goods proportion of dead weight...	3·26

Such a balance of traffic then reduces the rates to an average of 1·428 × 3·26 × 2 = 9·1 pies.* The proportion of freight to gross load in the trains is $\frac{261}{82·34}$ or as 1 to 3·15, (see last page), so that, on the whole, empty haulage in practice appears to add very little to the cost as determined with a vehicle average load of 3·35 tons.

As regards passenger traffic there will probably be very little

* It is probable that this is a low average; but it must be remembered that no absolute rate is being laid down, but an inquiry made as to the mode of ascertaining the rates.

variation on the average between the number in one direction and that in the other.

(*e*) Before proceeding to investigate the determination of passenger rates, let us see why the *average* paying load is 40 per cent.

Average paying freight.

Take the wagons to be represented by 5 and the loads from 1 to 6.

The paying load in a vehicle will be accordingly—

Vehicle.	Load.	Total.	Proportion of freight per cent.
5	1	6	16·6
5	2	7	28·6
5	3	8	37·5
5	4	9	44·4
5	5	10	50·0
5	6	11	55·5

Taking out the average proportion of goods offering on the G. I. P. and B. B. and C. I. Railways for an entire year, it is found that the whole is made up on the average of the following proportions of classes :—

	Per cent.
Special	14·83
1st Class	38·44
2nd "	22·24
3rd "	16·56
4th "	0·56
5th "	0·62
	93·30*

Now although the goods classification is not strictly framed with reference only to the bulk, yet certainly the bulk has generally been considered as the chief element in the classification. The special and 1st class contain such articles as wood, iron, gravel, salt (of which perhaps 6 tons will go into a 5-ton wagon); 2nd and 3rd, cotton piece goods, pressed cotton ; 3rd and 4th, furniture, &c. ; 5th, valuable articles.

* Railway materials omitted.

It would most likely be perfectly correct to take the weights of these six classes increasing as below :—

	Tons in a Wagon.		Proportion per cent.		Total.
Special	6	×	14·88	=	89·28
1st Class ...	5		38·44		192·20
2nd „ ...	4		22·24		88·96
3rd „ ...	3		16·56		49·68
4th „ ...	2		0·56		1·12
5th „ ...	1		0·62		0·62
	21×6 = 126		93·30		421·86

$$\frac{421\cdot86}{126} = 3\cdot35 \text{ tons per wagon.}$$

Total weight of freight and wagon...... 8·35 tons.

Proportion of freight, 40 per cent.

(*f*) To find the expense per passenger.

The velocity may be doubled with half the weight of train. The work done per hour will be the same in amount. Any other velocity may be adopted with a total load in inverse proportion. For the general traffic of very large lines there will be a high speed limited mail for vast distances; for local traffic,—passenger ordinary, and Parliamentary trains.

Train Expense (Passengers.)

The total work due to this line (5′ 6″) is 12 trains at 15¾ miles an hour, weighing 261 tons each, or an equivalent.

Take a speed of 31·5 miles an hour, double the goods velocity; any velocity will do; starting as before for goods—

The train staff will be	11·65 pies a mile.
	4
Staff and machinery	46·60
Fuel, &c.	46·60
Total net train cost......	93·20

Fuel, &c.	46·60	
Deduct—Grease, &c., 20 per cent.	9·32	
Pies per lb. ....2)	37·28	
	18·64	lbs. fuel per train mile.
	7	tons per lb.
Weight of train	130·48	tons.
Deduct—Engine, &c...........	53·30	„
Weight of vehicles and freight, say 8 tons)	77·18	tons, vehicles and loads.
	9·65	vehicles per train.

Number of passengers in each vehicle—

Average in Sind...............	13	
B. B. & C. I. ...	24	18
Madras............	18	

Total number of passengers $9{\cdot}65 \times 18 = 173$

$$\frac{\text{Train cost} \ldots\ldots\ 93{\cdot}20 \text{ pies.}}{\text{Number of passengers. } 173} = \cdot 523 \text{ each.*}$$

Add— Agency general, &c......	·523
	1·046
Add—Interest on capital.........	1·046
The average fare will be.........	2·092
say.........	2·1 pies.

* The weight of a passenger is so small compared with the weight of the carriage, that the rate at which each can be conveyed may be considered in practice for small differences, to vary inversely as the number that usually travel in it, without appreciable error.

(*g*) The number of 1st and 2nd class passengers is never more than 5 to 10 per cent. of the whole. The expense of their carriage will be $\frac{1}{9 \cdot 65}$ of the train cost for the vehicle, or 9·4 pies.

Fares.

Add—Agency, &c.	9·4
	18·8
Interest, &c..........	18·8
	37·6 pies.

Average number in each	1st Class...	1·5
Do.	2nd „ ...	5·0

The legitimate fares based on the assumed data would therefore be—

1st Class.........	25·0 pies
2nd „	7·5 pies;

but there is no doubt but that by lowering the 1st class fares, (considering they are now double the 2nd from Calcutta to Bombay) the number in the first class would vastly improve, and an advantage would result to the public at certainly no loss to the Railway Companies.

It seems wrong in principle to put such high rates on the 1st and 2nd as to virtually exclude the possibility of the carriages having a fair number in them. In the climate of India no doubt six passengers is a full load for the 1st class, as now designed for long distances, and ten might reasonably be expected in the 2nd for short; rates which would ensure this number would appear not to require to exceed 6·3 and 3·76 pies. respectively a mile.*

(*h*) It may be remarked here that the introduction of fast trains travelling at more than the economical velocity of the line must necessarily lessen the number of those

Adjustment of velocities for different Traffic.

* See note to Art. 44 (*f*).

proceeding at the economical velocity, for they cannot both continuously occupy the length between stations. The number of goods being diminished, the weight of such must be increased; thus the whole ton mile duty will remain the same, but goods will be longer on the road and passengers shorter.

The maximum effect of greatest weight over greatest distance in the shortest time, can, however, only be at the one economical velocity for the gauge. The number of goods possible to be run must depend on the number of fast passengers. The velocity of goods will continually decrease and weight increase as the number of passenger trains increases. When the number of them was one-third, the velocity would be 10·6 miles, and the number of vehicles 37½.

This proportion of trains is what obtains on the Bombay lines. Also as the proportionate number of passenger trains increases, their velocity should also increase in order that the times of crossing at stations may be as often identical as possible: thus with a proportion of one-third passenger trains the velocity should be $15{\cdot}75 \times 1{\cdot}66 = 21$ miles. The velocity being 21 miles, the number of vehicles for the same description of freight in each case would be 18·65; so it appears that the velocity of passenger trains should be double that of goods and the weight half to lose least power.

The number of vehicle miles per hour thus always remains the same, but if speed is required in some description of traffic it is sacrificed in others. There is no increase of cost for total work done. Also since the goods only travel at 10·55 miles an hour, it will be found more convenient to modify the distances of stations apart, accordingly reducing the cost of each in inverse proportion to the number. This does not appear to decrease the maximum power for the velocity of 15·75 miles. Trains will simply cross at intervals nearer to one another.

This being done also, will admit a special mail at three or

four times the velocity of the goods, with least delay to the rest of the traffic for its crossing.

(*i*) To complete the question of goods rates for each class reckoned by the bulk or tons that will go into the wagons up to the limit of their springs.

The weight available per train was shown to be 208 tons, exclusive of engine, tender, and brake, and the net cost of hauling it for the *trains only* 186·24 pies per ton a mile. The different classes and cost will therefore stand—

Class.	Tons in Wagon.	Proportion of Freight.	Total Freight, tons.	Net Train Cost, pies.
6th.........	1	11·6	25·4	7·625
5th.........	2	28·6	62·7	3·105
4th.........	3	37·6	82·1	2·371
3rd.........	4	44·4	97·3	2·000
2nd.........	5	50·0	109·6	1·776
1st.........	6	55·5	121·5	1·602

The absolute cost of conveying the classes of goods, supposing return vehicles to be full, is as shown above, provided the line is not in more than economical full work. The ordinary rates as shown before are made up—

Classes.	Train Cost.		Whole Cost including Agency, Direction, &c.		With Interest on Capital.		Including maximum balance of Traffic.
6th...	7·625		15·250		30·500		45·750
5th...	3·104		6·208		12·416		18·624
4th...	2·371	× 2 =	4·742	× 2 =	9·484	× 1·5 =	14·226
3rd...	2·000		4·000		8·000		12·000
2nd...	1·776		3·552		7·104		10·656
1st ...	1·602		3·204		6·408		9·612

It is instructive to observe how rapidly the rate decreases from the 6th to the middle class, or average rate taken before to be 13·26 pies (Art. 44 *d*), and how comparatively small an advantage is gained by increasing the loads in wagons beyond the medium.

(*k*) The G. I. P. Railway rates for ordinary traffic are—

Classes.	Up to 400 miles.	400 to 600.	Above 600 miles.
5th......	48	42	34
4th......	34	28	25
3rd......	24	22	20
2nd ...	14	14	13½
1st......	10	9½	9

The average goods receipts on the Bombay Railways have been for the last two or three years—

B. B. and C. I. Railway.........13½ pies per ton per mile.
G. I. P. Railway ....16 " "

The former has certainly a better goods traffic notwithstanding the sea competition.

(*l*) The above rates are based on the present prices of labour and fuel, and reckoning 7 tons to be worked over one mile by 1 lb. of English fuel. This is believed to be applicable to most of the railways in the plains, but it is evident that each will vary more or less, and that it is only by an accurate knowledge of the fuel expended on the average per ton hauled one mile, that fair lowest rates can be ascertained. In the absence of proper registers on most railways of the ton mileage, it is very difficult to fix the fuel consumption, but it could be calculated with great nicety. The work however being somewhat laborious, is probably never undertaken. It should be the duty of the Chief Engineer's Office. Actual registry would however be simple enough, and as it is the only real gauge of the work done, it is astonishing that it is considered of such small importance.

Loading of Vehicles.

(*m*) It will perhaps be clear that there is no advantage in loading a vehicle to a greater weight than the weight of the vehicle itself, from the following observations.

The two things affected in the working expenses are (1) repairs and wear; and (2) fuel consumption.

As regards the first (1) the requirements to ensure economy are maximum load with least wear and tear *per vehicle,* and

least wear *per ton of goods carried*; both these conditions must be satisfied.

The wear per vehicle will be least when it is empty. The wagon repairs to be charged on the goods will be as the whole weight of both together, and the amount per ton of goods will rapidly diminish as the load for, say, a 5-ton wagon is increased from 1 up to 5 tons, while the wear from the total load will not increase so fast; after the point of equality is passed the whole *wear of the vehicle* for the gross load, and for every extra ton, will increase in exact proportion to the weight of goods added, and the charge per ton of goods is in no way lessened. Thus the charge per ton of goods for wear of the vehicle is a minimum and the wear of the vehicle itself is a minimum, while the goods load is a maximum when the paying weight is equal to the dead weight, the repairs being then equally due to paying freight and weight of the vehicle. It is immaterial whether the wear is incurred in many or few vehicles, the amount must be a constant per ton of goods, and the stock of vehicles is a fixed proportion of the capital.

Next as regards the fuel consumption (2), if the increased weight of paying freight to dead weight is to be got by putting broad wagon bodies on narrow gauges, it is quite clear that the velocity of the train must be diminished in exact proportion to the gauge and degree of instability of the wagons; and since train and station staff are one-fifth of the whole working, and fuel, grease, &c., form also one-fifth, what is gained by saving in fuel, &c., must be lost through inferior velocity in the matter of train and station staff for the quantity of paying freight conveyed over a distance.

As regards heaping up the wagons of the proper form and stability. The fuel expended for the wagon's weight, per ton of goods carried in it, will be proportionally decreased as the freight increases from 1 ton to 5 tons: after that, the fuel, &c., required for the whole load of goods and wagon will increase as the weight of *goods* added; but since every ton of goods added to the empty wagon reduces the velocity for the same expenditure

of fuel, as the freight is increased the velocity is correspondingly diminished. Thus after the limit is reached (supposed to be 5 tons in a 5-ton wagon) when the freight equals the dead weight, the velocity would decrease with every additional *ton of goods.* This *maximum load* and *maximum velocity* must clearly result when dead load equals paying weight.

It may be said that the average dead load for the lines is lessened by overloading the full wagons to make up for the empty haulage. This however must be quite fallacious. It would appear so on paper, but as will have been seen, the effect on paper would be attained by loss of power on the line. It is impossible moreover to see how overloading a wagon in one direction can make it travel back empty with less fuel or repairs than was due to its own weight whether full or empty.

(*n*) Mr. Carl Pihl's report to the Government of Victoria states that—

"At the same time that on a narrow (3′ 6″) gauge a dead weight of 1·34 tons is moved for each ton of paying load, on the broad gauge (4′ 8½″) a dead weight of 1·77 tons is moved for each ton of paying load."

Now this seems in the abstract to be favourable to the narrow, and in point of fact, since the wagons and trains should vary in weight as the square of the gauge, it must be evident that without reference to the velocity at all, the dead weight in a large vehicle is greater in proportion than in a small one, but since larger wagons are to do larger work on a larger gauge in which velocity will be proportional to the gauge, the *work* done by the wagons will be exactly proportioned to the expense for repairs to them. (Art. 39 *e.*)

The gauges are as $\frac{3\cdot5}{4\cdot66} : \frac{1}{1\cdot33}$; according to Mr. Pihl's report the dead weights are as $\frac{1\cdot34}{1\cdot77} : \frac{1}{1\cdot33}$, which shows that the dead weights are accurately as shown to be required by the proportion of the gauges, and speaks well for the design of the stock

in that respect.* This fact, coupled with the percentage of repairs for vehicles given (Art. 43 *a*), leads to the inevitable conclusion that the dead weight considered without reference to the velocity is calculated utterly to mislead.

From this consideration it appears that when designing a system, we cannot do better than adhere to the stable construction for stock, and get our increased capacity in the legitimate way by adapting the gauge to the traffic, and having wagons and trains economically proportioned.

As regards the rates at which lines on different gauges can afford to carry, it will have become evident that whatever the gauge, so long as it is suited to the requirements, the force expended in capital and working expenses for a ton or any other weight carried any distance must suffice to carry it and no more or less, and it is in this particular that the economy of design of the particular line consists. The rates on different gauges should be the same. Also whatever the variety of gauge may be, the force actually expended in doing the same amount of paying work will be the same.

Thus although broad gauge lines may have been used to carry a traffic for which a narrower gauge would have sufficed, the working charges absolutely incurred, neglecting the interest on the excess capital and excess of fixed charges, have in no way been increased: nor can they be diminished by applying a narrower gauge; but of course the interest on excess capital and fixed charges would be saved. A reference to their probable amount will be found further on.

Cost of different Gauges.

45. A comparison of cost of different gauges based on the actual cost of the G. I. P. Railway, and all that has now been written, will show the cost and work to be expected.

* It is highly probable, however, that the vehicles are larger than due to the gauge, and fewer in number. Nothing is saved thereby.

Cost and Performance of similarly

The Total Capital.	Way, Bridges, Culverts, Ballast, &c.	Rolling Stock $\frac{1}{10}$th of the Capital.	Rails $\frac{1}{10}$th of Capital.	Sleepers, Chairs, and Fastenings $\frac{1}{10}$th.	Engines. (0·26 per mile) Price each.*	Engines. Amount, $\frac{1}{20}$th.	Vehicles. (4·25 per mile) Price each.*	Vehicles. Amount, $\frac{1}{20}$th.	Economical Velocity, Miles an Hour.	Economical Train load, in Tons, 12 Trains daily.
£	£	£	£	£	£	£	£	£	Miles.	Tons.
50,000	35,000	5,000	5,000	5,000	9,700	2,500	585·0	2,500	26·88	767·0
40,000	28,000	4,000	4,000	4,000	7,960	2,000	470·0	2,000	24·00	614·0
30,000	21,000	3,000	3,000	3,000	5,820	1,500	351·0	1,500	20·76	460·0
20,000	14,000	2,000	2,000	2,000	3,880	1,000	235·0	1,000	16·97	307·0
17,000	11,900	1,700	1,700	1,700	3,300	850	200·0	850	15·74	261·0
15,000	10,500	1,500	1,500	1,500	2,910	750	168·0	750	14·69	230·0
12,330	8,631	1,233	1,233	1,233	2,392	616	145·0	616	13·43	190·0
10,000	7,000	1,000	1,000	1,000	1,940	500	117·0	500	12·00	153·0
7,500	5,250	750	750	750	1,455	375	87·7	375	10·40	115·0
6,182	3,396	618	618	618	1,199	309	72·9	309	9·45	91·0
5,000	3,500	500	500	500	970	250	58·5	250	8·50	76·7
3,550	2,485	355	355	355	690	177	41·4	177	7·08	54·6
3,000	2,100	300	300	300	582	150	35·1	150	6·56	46·0
2,500	1,750	250	250	250	485	125	29·2	125	6·00	38·4
2,000	1,400	200	200	200	398	100	23·5	100	5·36	30·7
1,500	1,050	150	150	150	291	75	17·5	75	4·64	23·0
1,000	700	100	100	100	194	50	11·7	50	3·74	15·4

N.B.—The number of Trains is inversely as the gauge in the

* As the square of the gauge.

constructed Railways in India. (1 *Mile*).

Weight of Rails, Iron, costing £14½ in Way.	Gauge for equally Stable Stock.	Annual Earnings.			Annual Traffic.		Daily Traffic.		REMARKS.
		Gross 1.	Passengers 1/3.	Goods 2/3.	Passengers, at 2·1 pies.	Goods, at 13·26 pies.	Passengers.	Goods.	
lbs.	Feet.	£	£	£	No.	Tons.	No.	Tons.	
191·15	9·42	5,000	1,666	3,334	1,523,310	483,420	4,175	1,320	
152·93	8·44	4,000	1,333	2,667	1,218,760	386,715	3,340	1,050	
114·69	7·30	3,000	1,000	2,000	914,300	290,000	2,505	790	
76·46	5·94	2,000	666	1,334	609,380	193,420	1,670	530	
65·00	5·50	1,700	566	1,134	518,070	164,430	1,419	450	Indian 5′ 6″.
57·33	5·15	1,500	500	1,000	457,150	145,000	1,252	400	
46·94	4·66	1,233	411	822	369,900	127,740	1,015	350	English 4′ 8½″.
38·23	4·22	1,000	333	664	304,760	96,280	835	260	
28·65	3·75	750	250	500	228,920	72,500	626	200	
22·60	3·30	618	206	412	185,400	59,740	500	165	Metre gauge.
19·10	2·98	500	166	334	152,380	48,430	417	130	
13·56	2·50	355	118	236	106,200	34,220	290	95	Gaekwar's 2′6″gauge.
11·47	2·31	300	100	200	91,430	29,000	250	80	
9·55	2·11	250	83	167	76,190	24,215	208	65	
7·64	1·88	200	66	134	60,930	19,430	167	52	
5·73	1·63	150	50	100	45,710	14,500	125	40	
3·823	1·33	100	33	67	30,470	9,715	83	26	

same time, but the number per mile of line is constant.

Average Work now performed on some existing Railways.

(*a*) Average annual work per mile performed on the undermentioned railways:—

	Passengers.	Tons, Goods.
Sind........................	33,000	47,000
B. B. and C. I.	307,000	125,000
G. I. P.	150,000	90,000
Madras.	136,000	53,000

It will be observed that the gauge should be as the square root of the capital.

(*b*) Applying this to the Indian Railways as they appear to have hitherto worked, it would seem that as they have paid $3\frac{1}{2}$ per cent. instead of five, the capital should have been as $\frac{35}{50}$, or 70 per cent. instead of 100.

The gauge should, according to that, have been as $\sqrt{\frac{70}{100}}$, or ·836 of the present gauge or 4·598 feet, or 4′ 7″, so it is probable that, had the English 4′ $8\frac{1}{2}$″ gauge been fixed, it would have sufficed for the present development of traffic. But it is equally clear that we should have been much nearer a vast expenditure for doubling the lines than we are now. Moreover, it is a question whether a somewhat broader gauge would not have suited the English Railways, considering the large capital cost compared to the actual cost of construction. They have cost much more than the Indian Railways per mile, while their power is only 73 per cent. of them.

The consequence is, the lines are over-worked and accidents are constantly occurring, from the enormous number of trains struggling to pass one another. They have also not the average speed economically at command that a wider gauge would afford.

(*c*) The proportions for the expenditure on construction and working of a railway being fixed and unalterable whatever they may be, any departure to attain a single advantage on one side must be the occasion of disadvantage as regards economy somewhere else, in exact proportion, for the maximum effect can only be obtained with least amount of force applied for the

work to be done or least amount of any number of forces aggregating to make up the whole force.

A less force than this would not do the same amount of work, so by a reduction of power in any one of the constituent forces, an increase must be made in some of the others in order to do the same work. There is no *economy* therefore in departing from the proper *proportions* of an engine or machine, but its *size* may be adapted to any work. There may be good *reason* for departing from the proportions, but there cannot necessarily follow increased economy.

For instance, a uniform gauge may be desirable, necessitating lighter rails for lighter work than the main body of lines have to perform. There will be economy in rails, but the *roadway* and bridges, &c., which have cost nearly as much as that for the standard rail, will be more expensive than they need have been for a gauge suited to the traffic. For half the weight of rail only one-half the work can be done, and if the same wagons are used there can only be half the number of trains, and the station staff is not fully occupied. The velocity of the trains has to be less for the lighter rail, and the train staff must cost more, or if the same velocity or number of trains of equal weight were run as on the main system, the rails must inevitably wear out twice as fast. There is then certainly no more real economy in a rail disproportioned to the gauge—though there may be a convenience—than there is in a wagon of disproportionate weight for the gauge.

There are two or three other things that should be mentioned here. The supposed economy of the greatest weights of trains has been referred to, of greatest paying loads to dead weight, of slowest speed. These three conditions appear to have attracted the greatest attention, and to have resulted in all efforts being directed to the maximum in every case.

The fact is, however, that the maximum work done by the particular line depends on the consideration of all three together, and in addition the velocity, which seems to be lost sight of.

To convey a certain quantity of traffic over a certain distance

in a fixed time appears to require a fixed weight of trains, a fixed velocity, and a certain amount of constant dead weight for the traffic. The proportions will vary in a line of disproportionate gauge for the traffic, but no more and no less power can be used in the *aggregate* for doing the same amount of work on a line suited to the traffic.

All questions of working are therefore legitimately referable to the standard proportions required for different traffic and different gauges. All questions of power of engines and dead weight to paying load for augmenting the power of an existing gauge are seemingly beside the mark in a discussion on the proper gauge; for if you increase the weight of trains permanently, every other part of the works requires increasing. The proper increase would be given by doubling the lines of a uniform system using the train weights proper for the gauge and the existing pattern engines.

(*d*) The disadvantage of constantly using a small number of engines working up to their maximum power of traction for their weight is easily explained in its most salient features.

Overloading Steam Engines.

The pressure of steam from the boiler is required to be used at the highest power in the cylinders for the heavy load. The fire must be kept up to the full power when even the engines are standing, because the starting the train at all in a short time is the greatest effort that the engine has to make. To do this the steam from the boiler is let into the smoke stack through the jet pipe to keep up the draught and escapes into the air, doing no more work than burning a lot of fuel uselessly. Steam also escapes from the safety valves whenever the train ascends an incline, owing to the increased pressure; steam escapes from the safety valve also when it is cut off from the cylinder, when the train is running down inclines, or it is turned into the blast pipe to keep up the fire for the next incline.

Since the pressure is so great the boiler is taxed to its uttermost to produce the steam fast enough for the velocity. The ends of the tubes nearest the fire are rapidly burnt out with the

immense heat and friction of the heated gases, and the engines are more frequently in shops, with a most expensive operation of renewing tubes or piecing them, going on.

The number of engines required for the work should therefore be greater than will necessitate too near an approach to constant work, and this militates against the supposed advantage of collecting all the engine power into few engines of excessive weight each.

But by allowing proper loads and engines proportioned to the work, the pressure of steam can be equally maintained; it can always accumulate in the boiler during the descent of inclines and standing for short periods at stations. The only counter-balance is the increased load of engines *per train;* but since a still larger stock of engines would have to be kept for the whole traffic, if this load is not carried, it is evident that what would be saved in working expense would be lost in interest on capital, so that no real economy results.

It is certain that engines are worked with better effect well within their power, just the same as everything else, and not at the extreme limit of it. The boiler should be worked at a high pressure, for in this case the expansion of steam is made the most of, without any undue fuel consumption; but the pressure should not be indicated always at the maximum, for then the valves blow off with the least check; nor should the cylinder pressure be so great as to absorb the steam faster than it can be produced to give the economical velocity, for delay must then occur.

The weight of engines and evaporative surface each vary as the square of the gauge in the same proportion of engine. (Art. 39 *d.*) There is no advantage therefore in utilizing the whole weight of the engine for traction where speed and weight of train demand equal quantities of steam; but when a small load is to be taken with a small velocity a short distance, it may be done with advantage. Such, for instance, as in the case of pilot engines; ballasting from short leads; shunting; short local trains of passengers, &c.

Tank engines are generally used for this purpose; but tank engines would be quite unable to supply steam for high velocities for long distances or heavy loads with greatest effect for the gauge.

What has been said regarding the working of engines, rails, and carriages will perhaps show the importance of ascertaining the actual wear on lines in work, for it will be evident that with a sufficient stock of any of them beginning to give repairs at more than the rate of interest, indicating growth of traffic, the stock will deteriorate, as it cannot be repaired fast enough, and the half-yearly revenue account would moreover be paying for work which should have been capitalised by more engines, &c. The work of the lines in operation is always increasing, and the only just way of treating the revenue account is by keeping up the capital to the full limit required for the work actually performed. This excess of work over that due to the stock has however not yet occurred on Indian lines, for they have almost all their full complement of stock, while the work has only been about 70 per cent. of the amount due, and much capital has thus been spent on that account earlier than there was necessity for, as it turns out.

DUTY OF THE MATERIALS.

Actual Deterioration of Stock and Rails.

46 (*a*) Art. 44 *c* gives the proportion of repairs per train due, and it will be well to see how the figures affect the *general duty* of the stock and rails, and how far the results accord with practice.

To find the performance of the *engines and wagons* at the same velocity—

The Engines cost ....Rs. 33,000 (5′ 6″)
The Vehicles .... ,, 2,000 on the average.

The repairs per vehicle and engine will be inversely as the number of them in stock. If the line is supposed to have cost Rs. 1,70,000, the proportion due to each is Rs. $\frac{17,000}{2}$, and this gives 33,000) 8,500 (·26 engines per mile.
and 2,000) 8,500 (4·25 vehicles per mile.

Life of Engines and Vehicles.

(*b*) The money life of each Engine is 12·5 years.
Do. Vehicle is 10 years.

In order that the life may be prolonged to 20 years, a larger stock may be kept, so that there will be double the number of vehicles, and 1·6 times the number of engines than would be necessary if the life could be prolonged to 20 years; that is to say, that an engine or vehicle during its actual running is deteriorating at about 8 or 10 per cent., but as it is not running above half the year, the repair is reduced for the whole time to a rate of 5 per cent.

The rate of wear in the running trains will be therefore at 8 and 10 per cent. on their value.

Suppose the average rate of running must be 15·75 miles an hour for the 5′ 6″; the repairs *per running train* mile (trains all 261 tons in weight) will be 23·3 pies (Arts. 27, 40 *a*) according to the train proportions, for engines or wagons. (Art 44 *c.*) This modified for the number of trains which are shortened by the grease, water, and oil, by deducting ⅕th, gives 18·68 pies per train. This is the same as 261 tons × ·0714 pies (see Art. 44 *b.*) The money duty of each must therefore be—

Mileage of vehicles, Sind Railway, from commencement, for 10 years.

Engines		122,356
1st Class		201,912
2nd „		123,452
3rd „		137,051
Wagons, low		98,000
„	open	100,624
„	high	98,000
„	covered	109,000
„	brakes	202,000

This line has not sufficient traffic, but a full supply of stock.

Engines $\frac{\text{Rs. } 33{,}000}{18\cdot68 \text{ pies}} = 340{,}000$ miles.
17,000 per annum.
47 miles per day.

25 *Vehicles* in a train. $\Big\}\ \frac{18\cdot68}{25} = \cdot7472$ pies each.

$\frac{\text{Rs. } 2000 \times 12 \times 16}{\cdot7472} = 514{,}000$ miles.
25,702 per annum.
70 per day.

For a mixed train mileage of equal amount for passengers and goods, the duty of engines would be about ⅓rd more train miles at 195 tons per train, or 453,333 miles. Vehicle mileage would be unaltered.

Life of Rails.

(c) As regards the *life of the rails*, it has been shown that the duty of the line is 87,600 trains of 261 tons each at 15¾ miles per hour (Art. 44 *b*), *i.e.*, 12 trains a day for 20 years. But when the renewal of the rails takes place, there is a credit for value of old iron over and above the cost of relaying, and it is very possible that the receipt to the P. W. Renewal Fund on this account will be generally one-fourth of the first expense.

The whole expense of renewal of rails at 5 per cent. should amount to the first cost in 20 years; in that time 87,600 trains should pass over the line; but as we require to find at the end of 20 years that the rails are as good as they were at starting with the actual work they have then performed, and that the total expense has been equal to the first cost of the rails, it is necessary that the credit for materials should also be included in the expenditure of that period, and this may be done if the rails are renewed after 15 years, with three-fourths the number of trains, or 65,700 over each of them.

This is on the supposition that trains of the proper weight are run at the economical velocity or their equivalent.

The tons hauled, however, is a more general indication of the work done, and would be 1,143,400 tons (Art. 44 *b*) for 15 years, giving a total duty of 17,151,000 tons.

It will be remembered that the duty of the line in tons is obtained from the number of tons hauled per lb. of fuel. The expenditure on coal also being a fixed proportion of the whole, the quantity to be consumed will be altered for its price. Thus with a dearer coal, a less total weight duty will be required from the rails to maintain the proportion. By reference to the train proportions, however, it will be evident that economical considerations will render the trains being made shorter desirable; the whole traffic will cost more to carry. Also if the number of tons hauled per lb. is less, it will probably be on account of steeper gradients or other difficulties. The duty in tons hauled will be less, but the wear will be most possibly the same in both cases, the cost of carriage will be increased.

(*d*) For instance, the expense of a line is increased for steeper gradients, the expense of working it is also increased, and to take an example of 1 in 40, here gravity forms 56 lbs. per ton of load, and since it requires about 10 lbs. per ton at 15 miles an hour, gravity alone makes six times as much as the load and the work to be done by the fuel; the train weights for the same line would have to be diminished accordingly.

Duty of Rails on gradients.

To carry the whole quantity of traffic over the steep gradient of the same line, the number of trains would have to be increased in proportion to the decrease in weight of each, so that there is no saving in the whole working from the smaller train weight, while the cost of repairs for each train would be unaltered.

The expense of working however would be exactly in proportion to the gradient for all services, owing to the increased number of trains.

Thus the duty of 65,700 trains for rails alluded to, would on a falling slope of 1 in 112, where gravity would be double the traction on the level under ordinary circumstances, be reduced to 32,850 trains, &c., &c.

The duty of rails on rising and falling gradients on double lines is found to vary much, and the explanation of it is probably this, that in rising the work of moving the train is performed by the engine, whereas in falling the work is performed by gravity and the rails, either in sustaining increased momentum owing to velocity, or in destroying the effect of gravity by the friction of wheels by the action of the brakes.

The renewal for both rails and rolling stock taken together is a constant, so that on equal traffic both ways over the same gradients, the proportion will not be affected, but in ascending there will be more wear of the latter and in descending there will be more of the former.

(*e*) It will be remembered that the duties of stock and rails are all determined with reference to their capital cost, and as the capital cost proportion is the same for all

Duty in Miles run is constant.

gauges the duty will be the same estimated in miles run, whatever the gauge, if the proportion of parts are the same.

The duty in tons, however, is strictly referable to the weight of the rail.

Life of Rails on English lines.

(*f*) The weight for the 4′ 8½″ gauge, other things being equal, should be 47 lbs.* Mr. Price Williams, in his valuable paper appearing in the Institute Proceedings, March 20th, 1866, informs us that the Great Northern rails were 82 lbs. to the yard, and that they wore out with a duty of 62,399 trains, or 12,451,784 tons on an incline of 1 in 130 in 7½ years, the traffic being of a mixed character.

The gradient here represents 17·66 lbs. of gravity per ton of load, and taking 10 lbs. as the resistance at 15 miles an hour the accelerating force of gravity would have been about 1·76 times that required for the motion of the trains at their normal velocity on the level.

The rails themselves being the best sample experimented on, were 1·80 times heavier than those due for the gauge, and only lasted half the proper life of, say, 15 years. This seems to tally nearly with the proportionate duty of the rails given in Art. 46 *c*;† but as the rails were not all so good as this, the average would no doubt be lower, and by an inspection of the tables in the paper alluded to, it will be seen that this was the case. The subject is, however, too large to go deeply into in this place.

At another point 65,529 trains and 13,484,661 tons destroyed the rails on 1 in 200 in 3 years. Here gravity was only 11·2 lbs., 12 per cent. in excess of the force required,

* In India. In England the price being lower might make the economical weight of rail greater.

† 70 per cent. of 17,151,000 for the 5′ 6″ = 12,005,700 for the 4′ 8½″. It may be noted here that the ton mileage estimated from the traffic mileage in Sind for the 10 years ending 30th June 1870, *i. e.*, from opening, was 6,201,310 tons for each rail; about 73 per cent. of that due to full work, and tallying remarkably with the fuel consumption (page 51.)

giving the duty on the level at 11,866,509 tons. There is a difficulty in drawing a comparison owing to the velocity not being known. Table 7 shows that Thornycroft's *best* iron rails averaged about 27 million tons on the level, and if the rail weight was 82 lbs., the duty would be 14,000,000 tons for the rail due to the gauge; the average life was 5·7 years. The velocity on this line (Lancashire) appears to have been much slower, but all the rails were not so good.

The total renewals seem to have been £200 a mile, in another instance, on a road costing originally £1,940, giving renewals at 10 per cent. As the rails only lasted about 7½ years, this seems to agree with 5 per cent. on first value with a life of 15 years and half the work.

Engine Repairs.

(*g*) The engine repairs have been ascertained by the present method to be 18·68 pies per train mile, (Art. 46 *a*). Vol. 24 of the Civil Engineers' Proceedings gives an admirable paper on maintenance of rails and rolling stock by Edward Fletcher, with most interesting discussions thereon.

In the course of the report it will be observed that the life of the engines of the present day is put at about 500,000 miles. Mr. Bidder also gave 1½*d.* a mile as the cost of engine repairs or 12 pies.* This gentleman also remarked on the general equality of cost of repairs in engines and vehicles, and that the gross receipts and value of the rolling stock were generally equal.

Rail Repairs.

(*h*) The repairs ascertained for rails are 18·68 × 2 or 37·26 pies per train mile; the weight of trains being 261 tons and velocity 15·75 miles.

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* Art. 39 (*d*) gives the price of English engines at £2,331. As it is believed it exceeds this, they are possibly proportionally heavier than those on the Indian 5′ 6″. £2,331 ÷ 500,000 miles = 1·14*d* = 9·12 pies, which would be more in proportion to the gauge, on a mixed train mileage, on the 4′ 8½″. A mixed mileage of equal passengers and goods would give corresponding Indian rate = 18·68 + 9·34 ÷ 2 × ·7 = 9·8 pies.

Figures in this place as in all others where dependence on the number of trains is concerned in treating of the *train* proportions must be modified for the deduction made from fuel, grease, oil, and water for all except the fuel; for we have seen that the number of trains is increased in proportion to the cost of these items (Art. 32), and to the extent of $\frac{1}{5}$th, and the expense per train must be diminished accordingly. Thus $23{\cdot}3 \times \frac{4}{5} \times 2 = 37{\cdot}3$ pies will be the Revenue account proportion for rails, and would come to $\frac{37{\cdot}3}{261} = {\cdot}1428$ per ton mile of the train which agrees with Art. 44 (*b*). A mixed train mileage of 194 ton trains would give 24·8 pies per train mile.

Mr. Bidder said he thought $\frac{5}{8}$ths of a penny would be sufficient for rail renewals per train mile.

This was for a gauge 85 per cent. of the Indian, giving proportional train weights and velocities 37 per cent. less each = 73 per cent. more work in the 5′ 6″.

It would make his rate appear too low considering the engines alone cost 9·12 pies. (Note on previous page.)

(*i*) The average number of engines employed on the G. I. P. during the last 10 years has been 179·48; price each Rs. 33,500; total capital cost Rs. 60,12,580. The renewals during that time have been Rs. 50,41,340 which would give an average money life of 12 years, and average cost of repairs each engine Rs. 28,000 for 10 years. The cost of engine and vehicle repairs has been :—

Carriages, Wagons, and Trucks..	Rs.	5,59,114	per annum.
Engines..............................	,,	4,58,303	

The difference in the charges is remarkably regular in the long run; it may arise partly from excess of capital stock in vehicles, which has very possibly been the case till lately, or in excess work on the ghauts or heavy gradients, while difference may also arise from the mode of apportioning workshop charges.

Effect of Inclines on the Engine and Vehicle proportion of Repairs.

(*j*) The effect of gravity has to be overcome by the engine

in place of the friction of the vehicles, and the number of the latter must necessarily be reduced at the same velocity.

The gradient being steepened more and more would at last reach a limit when the engine could only take one single carriage up the incline at the same velocity; the limit of the gradient may be taken at 1 in 7½, beyond which iron on iron will not ordinarily adhere.

The force exerted by gravity would then be about 300 lbs. per ton. Suppose the traction on the level at 15 miles an hour to demand a power of 10 pounds per ton of load, the force of gravity would be 30 times this. The engine would thus be capable of hauling 30 vehicles at the same velocity on the level as one on the incline of 1 in 7½.*

Now it must be evident that the engine repairs for the whole work done being the same in both cases the proportion of repairs to repairs for vehicles going up the incline must be as 30 to 1, and that on the level the proportion must be 30 to 30. The vehicles appear to be simply a little lightened by the drag on the engine, the effect being to take some of the weight off the rails, which carried to the utmost limit of a steep gradient would be when the vehicles were suspended altogether, the road having become vertical; the friction in this way must be less injurious to individual wagons the steeper the grade. The proportionate wear of the engine is thus increased for ascending, while the wear of vehicles is each decreased. *Now in descending* at the same velocity which we will adhere to for the sake of clearness, the engine is called on to exert no power. The effect of gravity is 300 lbs. per ton, so that it is 30 times that required to maintain the velocity; it is consequently necessary to destroy the excess of 29 times the accelerating force on the level, which is done by increasing the friction.

In this case the work of retardation appears to be done by the rails, wheel tires, and brake blocks of both engines and vehicles,

* This seems to prescribe the natural limit to the load of an engine.

if the slope is so steep as to require so much brake power: the destruction must therefore be mainly confined to those parts. The engines will be worn in proportion to their weight, and the train the same; each could run down the incline by itself. The proportion of repairs of the train for both will depend on the gradient, and will only be equal on a gradient giving a weight of train equal to the weight of the engine. Now since only as many vehicles can come down the incline as go up, on the whole it is immaterial whether some engines come down 'empty' and others with a greater load, the whole wear will be the same as if each engine brought down as many as it took up. The proportion of wear coming down will therefore also depend on the gradients, and with 1 in 7½ would give a very large excess of engines; but ordinarily the slope is not so great, and the weight of the vehicles is almost always greater than the engines, and to this extent the wear of the vehicles if they are braked will exceed that of the engines in coming down.

It is not intended to pursue the argument to the actual figures, which would take up much space; but it seems that there can be little doubt of the general correctness of the supposed incidence of the wear owing to the inclines of a railway. Also it seems that the wear per ton of freight will be the same whether it occurs chiefly in engines or vehicles, and that the cost is consequently unaffected by the proportion of them to one another.

The wear of vehicles, though taking place at a different time, is produced in proportion to the gradients, the same as in everything else, and the rails and permament way which have to sustain the united wear of the engines and vehicles are worn in exactly the same proportion.

Now since the total work performed by the fuel includes a proportion due to the gradients also, and the time taken up will also be as the gradients, there will be an excess in all the charges for a train in exact proportion to the gradients, including train and station staff.

The excess in the latter occurs evidently by less distance being done in the same time. This shows that the train proportion for all expenses as given in Art. 24 *g* will not be affected by the introduction of gradients except in the matter of engine and vehicle repairs, which with rails form a class the proportion of which to the other classes is constant.

(*k*) In 1855, Mr. Carr transmitted a valuable record of Maintenance to the Institution, of which the following is a summary :—

GREAT NORTHERN RAILWAY.

Retford to Doncaster district.

Cost of Maintenance of 18 *miles of Permanent Way in* 1853. (*Labour only.*)*

	Up Line.	Down Line.	Total.
Labour for 12 Months.........*days*	3,850	1,939	5,789
„ giving per mile, per annum.	213·888	107·722	321·610
„ „ per day ...	0·712	0·359	1·071
(taking 300 working days a year.)			
Cost of labour per mile per annum, at an average of 2-8 per man, per day	£ 28·5	£ 14·35	£ 42·85
Gross weight passing over the district during two weeks	Tons. 72,116	Tons. 41,377	Tons. 113,493
Proportion of gross *weight* passing over "up" to "down" ...	1·742	1	...
Proportion of *labour* on the same.	1·980	1	...

This clearly shows the labour of maintenance is as the work done by the line. The great difference of traffic on the two lines is owing to the coal trains to London; the author of the paper seemed to think, that the heavy description of traffic would

* The materials used were stated to be equal in amount to the labour, though what they consisted of is not stated.

account for the excess wear in proportion to the excess weight as it might be expected that it would cause more than any other. This, however, does not of itself seem as likely as that the excess was due to the falling gradients towards London. Unfortunately no allusion is made to the gradients in the paper.

The weights moved over the lines would, at the same rate as for the two weeks observed, be—

$$\underbrace{\begin{array}{cc}\text{Up} & \text{Down.}\\ 1{,}556{,}808 & 889{,}605\end{array}}_{2{,}446{,}413}\ \text{tons annually.}$$

At this rate the maintenance would be represented by ·033 *pies per ton mile* for labour only.*

Mr. Carr's observation in regard to the companies boldly meeting the question of maintenance without fear of the consequences to the present value of their shares in the market, and his allusion to the system which it was feared prevented the Resident Engineers from comparing notes for their mutual benefit owing to the liability to injury of him who told the whole truth, is significant, and accounts for much of the obscurity in which it always seems railway accounts and operations have been purposely veiled.

47. COMPARISON OF CAPACITY OF 5′ 6″ AND 3′ 3″ GAUGE BY REFERENCE TO THE NUMBER OF MEN WITH THEIR PERSONAL KIT THAT CAN BE TRANSPORTED PER DAY.

This comparison can most easily be made not by reference to any particular constructed length, but by reference to the standard proportions which should regulate the construction and working of such lines. The *work* a line is capable of performing should in such comparisons be exactly propor-

* Art. 42 gives the labour proportion to whole cost of P. W. at 2,126 + 727 = 2,853 Rs. = 8 per cent. on Rs. 34,600. Art. 44 *b* gives the repairs of P. W. at ·1428 × 2 pies, and 8 per cent. of this would give ·0228 pies per ton mile for labour only. The wages are much higher in England.

tional to the capital expended, and the work is in all cases precisely referable to the number of tons hauled, this being in fact the total duty.

The power of the line to do any part of the work in a given time depends on the velocity that can be constantly maintained.

Thus, although the total duty of a pound of iron in the rails, for instance, is the same whatever the gauge, the total duty will be accomplished so much the quicker in a gauge affording a larger velocity. In this way the duty of the whole of the material and labour expended in the form of capital will always be constant, but the power of the line to quickly accomplish the duty depends on the greatest velocity which can *constantly* be maintained.

It seems an easy thing to run a train on a narrow gauge at a high velocity, and in that way to appear to show that it is as fitted as a broader to carry as fast; but unless the velocity can be maintained constantly, the greatest effect cannot *continue* to be produced for any length of time.

There is accordingly an economical velocity for every gauge which will produce the effect of the largest weight transported the longest distance in a given time.

Thus it is quite true that it is the same thing as regards the power expended, and the consequent expense, whether a train is twice as long and travels half as fast or travels twice as fast and is half as long; but as this applies equally to every gauge, there seems to be no reason for departing from the speed which gives the maximum effect for distances as well as for weights transported. As a broader gauge admits of greater velocity in proportion to its width, by availing ourselves of the velocity we are able not only to transport weights in proportion to the gauge, but also take them distances in like proportion, so that with a gauge double as broad, four times the work can be done in the same time.

The capital expended on the construction of the line must be exactly proportional to the whole *work* to be done, and

consequently must, with a gauge of double the width, be four times in amount; but since four times the work is capable of being performed, there is no excess in cost for the whole work to be done.

The Bombay 5′ 6″ being taken to have cost £17,000 a mile, the relative duty, power, and cost of the metre gauge would in similar circumstances of cost and working be as below* :—

The Duty.

5′ 6″ cost £ 17,000; 3,131 tons daily; 261 tons an hour.

3′ 3″ „ £ 6,182; 1,095·8 „ „ 91·3 „ „

Also the *power* of the line to do this must be as the velocity, which is as the gauge. The work done which is equal to the power expended, will be as below:—

Cost. £	Wt. of trains.	Velocity, in Miles.	Work per hour per train.	No. of trains moving.	Total work of line per hour.†	*Ratio.*
5′ 6″...17,000	261·0	15·75	4110·00	1·00	4110	·100
3′ 3″... 6,182	91·3	9·43	860·95	1·66	1429	35

Since the capacity is as the square of the gauge, the gauge must be as the square root of the capacity required.

To simplify the subject take a required capacity of 2. The gauge must then be $\sqrt{2}$ or 1·4.

Trains of this capacity or weight will travel at a velocity of 1·4. *The work* done by each will be as 1·4 × 1·4 or 2, while the weight of the freight carried at the same time will be only 1·4. There would thus be a disproportion between the freight weight and the repairs to the rolling stock, because the wagons would do work in greater proportion to the increased load, by the amount of increased distance. The strength of wagons or their weight, which may be taken as the measure of their strength, would have to be increased as the amount of work or distance travelled in excess of that required for the excess load, and consequently the weight would have to be 1·4 times as much, or 2 altogether. Weights of trains, wagons, and

* Art. 45. † Ton miles.

engines would increase in proportion to the freights in larger gauges and *vice versâ*, and in direct proportion to the gauges, and they would therefore in all cases for similar stock be as the square of the gauge in weight; but as they would then simply be in proportion to the actual work done, the cost per ton mile both for construction and maintenance—the former varying as the weight or square of the gauge (Art. 39 *d*)—would be constant.

Since the capacity of trains and wagons should vary as the gauge, the number required to take the *same quantity* of traffic would be as the gauge inversely. This must apparently be true for all gauges and similar rolling stock.

The only gauges which will give the maximum results of work are those in which maximum stability of rolling stock is combined with smallest gauge. There can only be one maximum and therefore one form, but that form may be adapted to any size for a given work.

Under the above circumstances, the performance of the two gauges will be—

	5′ 6″	3′ 3″
Train weight.............	261	91·03
Deduct—Engine, brakes, &c.	53	18·55
Train	208 tons	72·75 tons.
	23·11 Vehicles at 9 tons each including 2 tons freight.	23·11 Vehicles at 3·15 tons each including ·7 tons freight.

In the former case 30 men will go in a vehicle, in the latter, at the same area per man, 10·5.

The number of men that can be taken in one direction only will be :—

	Per Train.	Per day, 12 hours.	Proportion.
5′ 6″.........	693·300	4159·80	100
3′ 3″.........	242·655	1455·93	35

As regards the working expenses of various gauges they are the same per ton per mile on the same ground, and under the same circumstances, in all cases where the loads and

velocities are in complementary proportion, and the capital expended is in direct proportion to the traffic.

As regards the increase of capacity in the unstable overhanging stock, that capacity leads to delusive conclusions, less distance being done than if the stock were stable, and there is no saving in expense. Such stock being in weight possibly much over that proportional to the square of the gauge, a less number in the trains may afford the same total floor space, but no more can be hauled per train than the engine can draw, so that nothing is gained in that direction and the instability and overweighting of the wheels by the large bodies and loads causes undue wear and oscillation which necessitates a less velocity and consequently a loss of *power*.

If it is proposed to take the same number of vehicles of an overhanging pattern as would go to a train load of vehicles of a proper weight for the gauge (*i.e.*, the square of it), it would be necessary to increase the size and weight of the engines, and to do this would be either to carry all the traffic in less than twelve trains a day which would leave the line idle for some part of the day, or to acknowledge that the line had been made insufficient for the traffic. It is quite immaterial whether money is spent on engines, rails, and vehicles on the one hand, or embankments, ballast, and bridges on the other, so long as the carrying cost is no more; and since the advantage of the increased gauge is apparent in velocity as well as weight, while the small gauge must continue at increased weights only, there is no advantage in adhering to the smaller gauge for a traffic greater than that due to it, for the expense per ton will remain the same. The power to do work in a given time rests with the velocity alone.

Referring to Art. 44 *h* it will be seen that under any ordinary system of passenger and goods traffic in which the proportions of trains are as one passenger to two goods, the speed for the former will delay the latter, and the through velocity of each for the smaller gauge will be 12·57 and 6·286 miles respectively; also the loads in number of vehicles will be the same

as in the 5′ 6″, *viz.*, 18·65 and 37½. The total work cannot, however, exceed the maximum for a length of time.

Possibility of getting excess work out of a line in emergency.

(*a*) As regards the possibility of getting work out of any line in excess of the normal amount, it may be done for a short time by working night trains. The quantity of rolling stock will always be in proportion to the capital cost, and allows for perhaps not more than 70 per cent. of the engines, and 50 per cent. of the stock running at any one moment. All such spare stock might be used for a single day or perhaps many days, but repairs would soon require to be done, for which stock would have to be taken into shops; also many engines would be under renewal at all times, so that not even the above amount of stock could be counted on.

It would be possible to concentrate stock from other portions of the line to work a particular part of course, but under all circumstances it is doubtful whether any great effect would be produced by such an arrangement over a wide area; additional sidings would be wanted to prevent blocks to the trains, for which material might not be at hand immediately. It is most probable that the line would do no more than run perhaps 50 per cent. more trains by working at night, and that they could not do so for more than a month or two, without increase to stock. The greatest alacrity would be required in all branches of the administration. The engines could under no circumstances do more work than they were designed to do, so that neither velocity nor weight of trains could *both* be increased.

(*b*) If the possibility of constantly running more than the economical number of trains on any gauge is contemplated, it will be seen by reference to the Art. on English railways that such an unfortunate necessity in ordinary working may arise owing to the enormous amount of unproductive capital spent on the lines, but no necessity need occur where such has not been the case; were this incubus removed, there would be room for the legitimate expansion of the capital accounts with the expansion of traffic in the shape of double or quad-

ruple lines with a possible total cessation of the terrible accidents constantly occurring, and increased prosperity to the country with no diminution of dividends, and a healthy state of the stock.

Before quitting the comparison of gauges, it will be well to note that to perform a given quantity of work requires a fixed capital. This capital may be truly invested in a smaller number of lines having a broader gauge, or a larger number of lines having a smaller gauge. The table given in Art. 45 shows that four miles, or a quadrupled line on a 3 feet gauge, will be equal to 1 mile on a 6 feet gauge in cost and performance, but we must not lose sight of the fact that in one case the average velocity is 8·5 miles an hour, and in the other 17, without any more expense; and that whereas a journey from Bombay to Calcutta might be made by one line in 2½ days or less, the other gauge cannot do the same journey constantly, allowing other traffic to work, in less than double or 5 days. In vast distances, the advantage of superior velocity must not be under-rated.

Already goods at 10 miles an hour would take 12 days to travel from Bombay to Calcutta, what would this rate be for a narrower gauge which had also to allow time for the passenger trains on the road?

Effect of working a line beyond its maximum economical limits.

(*c*) The possibility of getting a large quantity of work out of a small capital investment in construction seems tantalisingly near when we purpose to effect it by running an unlimited traffic over the same lines of rails, for don't we save the cost of the railway bridges, stations, &c., and have we not simply to continually run the same stock of heavy trains over light rails to earn an enormous dividend?—at no expense for interest on anything else! When we stop to inquire, however, we perceive that for a totally extended traffic we require rolling stock, rails, sidings, crossing places, and stations, exactly in proportion to our traffic. It is possible to take trains over the *same* rails to a very large extent, but their total capability of

duty is fixed, and if that is exceeded in the *time*, they must be more frequently renewed. There can be no difference in total expense if more capital is expended up to the interest limit of the wear, and the frequent renewal reduced. The ballast and sleepers must be adjusted in proportion to the traffic. As regards all the other items of construction, their repair has been shown to be almost *nil* compared to that of the permanent way and rolling stock, so what goes with the saving of interest by utilising them for excess work! There is the interest on 60 per cent. of the capital to account for. Well against this has to be debited the extra expense for working, which would not be required with more capital expended on the new roadway. It perhaps may be recognised from the following:

Station Staff.—Cost of the increased number of signallers and line guards, &c., who are placed very near together in English Railways, perhaps two or three miles apart.

Train Staff.—Pilot Engines and various services where repairs are going on, additional delay to trains in a mixed traffic for crossing, where the number of trains is very large.

Maintenance.—Waste of time of permanent way gangs waiting between rapidly following trains, to take up and relay rails and pack the road. Damage to stock from the impossibility of doing the packing properly in the time.

Stock and Rails.—Greater running speed necessitated by crossing arrangements in a mixed traffic with a large number of trains.

Fuel.—Waste while standing in steam for crossing. Also excess while running for excess loads and speed.

Miscellaneous.—Liability to accident by frequency of trains, and absorption of large amount of revenue in damage to rolling stock and rails; compensation for injury from collisions, law, &c.

The rolling stock, rails, and permanent way being subject to the increased velocity for trains while actually running will be worn in exact proportion. The question then suggests itself—is not this made up for by the saving in train and station staff, according to all that has been said on the subject, or by

increased train weights in the delayed trains? The fact is that the line which was before in full work for the capital invested, supposing it to have double the work put on it, with 40 per cent. more capital spent, is virtually expected to do 60 per cent. more work than before in the same time. The capital and work will then be as—

	Capital.	Work.
	100	100
	40	100
Total capital...	140	200
Average of the two...	70	100;

so that 70 per cent. of the capital is expected to do the same work; this gives an apparent saving, and, *if possible,* could afford a dividend of 1·43 against 1·00.*

But no actual saving takes place for train and station staff, first, because the delay at crossing stations more than makes up for smaller driving and train charges at greater running velocity, while the delay at stations can in no respect make up for increased wear of stock and rails from faster driving. The trains also for the same class of engine cannot be increased; for increased velocity they must either be smaller, or more fuel must be consumed per mile for the increased weight of train. In this way the actual train and station staff, fuel or repair charges, must one or other be in excess, to do the 60 per cent. more work in the time, and the ton mile charges can in no way be lessened.

In practice the excess will be divided equally over all the above items of the trains. They will be a little heavier, the running will be a little faster, and the delays at the sidings a little longer. This is after all in perfect accord with the experience of every machine; more work cannot continue to be done without increased power in the same time; and there can only be one maximum effect, that is, when all the parts of the machine are in perfect equilibrium of working.

* The receipts may be in this proportion (see next page) but not the dividend.

More of the power may be employed on the working expenses side and less on the side of capital, and *vice versâ*, but no more or less than the effort represented by the sum of the two, can be made to do the same work. The dividends and working expenses of English railways bear this out. The ton mile expense is almost identical on Indian and English railways, and dividends are not above the average rate of other profits.

(*d*) It appears from the Board of Trade returns for 1871 that the mileage and cost of railways in England was as follows:—

Year.	Length open. Double.	Single.	Cost per Mile open.	Cost per track Mile.
1852 ...	5,878	1,458	£33,283	£18,305
1867 ...	7,844	6,403	£35,113	£24,475

The increase in both single and double line has been regular from 1852 to 1867, but the former has made more rapid strides than the latter. The cost per mile of single track has increased 33 per cent. or £6,167 a mile. It is very probable this increase has been made in the rails (I), sleepers and fastenings (II), rolling stock (III), and stations (IV), and most possibly in equal proportions, which would give the increase at £1,542 a mile for each.

The receipts from the lines have been per single track mile—

1852..................................£1,177
1867..................................£1,772

an increase of 50 per cent. or £595. With an increased expenditure per mile of 33 per cent., the receipts have increased 50 per cent., which to a superficial observer may appear satisfactory;* but on consideration it will be seen that the gross earning due on the excess capital of £6,167 is £616, or one-tenth for a return of 5 per cent., whereas only £595 was received, which however may be the amount due to the average rate of profit.

Also the rate of dividend does not appear to have increased at all, and the conclusion must inevitably force itself that increased working expenses consequent on working the lines

* An analagous case to that given on the previous page.

beyond the economical maximum must have reduced the net receipts by the equivalent of capital interest saved by not wholly increasing the lines by a proportional expenditure in every direction equally. In order to save the capital outlay involved in doubling the lines with the same weight of permanent way, the trains are crowded into a single track, thus causing increased expense in every department of the working, with no better effect whatever; but that this state of things has arisen from the circumstances of the unproductive capital burden can easily be understood.

INDIAN RAILWAYS.

Comparison of theoretical proportions of expenditure with actuals.

48. *Comparison* of theoretically ascertained proportions with the actuals as near as can be ascertained.

The earnings and expenses of the *Indian* lines for 1871 are given in the *Government Gazette* at

	Earnings.	Expenses.	Mileage.
	Rs. 6,68,74,586	3,76,28,629	5,030
Per mile weekly	......255·6	144	$\frac{1}{52}$

The capital of a mile will be about Rs. 1,70,000, giving a required *weekly* gross receipt of Rs. 327, and a working expense of Rs. 163·5 per week.

The receipts have been 78 per cent. only of the required amount. The expenses have been 88 per cent.

(*a*) The expenses appear therefore to have been much higher than warranted by the receipts, and to the extent of 11·4 per cent.

It is most probable the excess occurs in maintenance of the way, station staff, and other fixed charges. The outlay on account of the former, excluding the permanent way for 1871, is 46,03,925, or Rs. 915 per mile per annum. This should represent 10 per cent. of the working charge. For the line to be in full work, the working charge should be 8,500, of which 10 per cent. is 850. The charge of Rs. 915, however, includes the

whole of the superintendence, which evidently is chargeable equally to the permanent way.

The permanent way renewals are entered at Rs. 3,95,11,834, or Rs. 785 a mile, which is below the proper amount. This cost includes the whole of the wages on ballasting and laying permanent way, and these are partly chargeable to the first class of works.

The sum of the two charges for the whole maintenance is Rs. 1,700, which gives 850 for each class, or exactly the amount required supposing the line to be in full working order.

The total expenses for Indian railways are given in pages 140 and 877 of the *Government Gazette* for 1872.

—	Maintenance of Way, Works, and Stations.	Locomotive and Carriage.	Traffic.	General.	Special.	Total.
1st Half, 1872	37,71,035	73,79,914	36,93,230	18,31,330	15,80,310	1,87,55,869
2nd „ „	40,43,643	74,31,713	34,08,609	18,72,463	12,04,673	1,79,61,106
5,030 Miles open......	78,14,678	1,53,11,627	71,01,839	37,03,798	27,84,933	3,67,16,975
Per mile	1562·934	3062·325	1420·378	740·760	556·996	7243·

But in Special and Miscellaneous is included large payments to special funds for maintenance which amounted to

1st Half..................	Rs.	9,63,064
2nd	„	7,27,611

Rs. 16,90,675 or Rs. 338·135 per mile.

And against these funds were charged for maintenance

1st Half....................	Rs.	4,27,461
2nd „	„	2,84,689

Rs. 7,12,150 or Rs. 142·43 per mile.

The actual figures for the year, deducting the former and adding the latter, would be—

	Per mile.
Maintenance	1705·
Locomotive and Carriage	3062·
Traffic	1420·
General	740·
Special	218·
Total......	7145·

Now the above figures include 13,44,075 under the head of "General," which belongs to traffic at stations, viz., Police and Electric Telegraphs = Rs. 268·817 a mile; also Rs. 30,75,804 for driving and fuelling which belong to train staff and not locomotive = Rs. 615 a mile. Locomotive and traffic include the heads of departments and offices, which more properly belong to general charges = Rs. 21,01,496, or Rs. 420 per mile. Making these adjustments, the charges become—

Maintenance.	Loco. &c.	Traffic.	General.	Special.	Total.
1705	3062	1420	740	218	7145
......	— 247	— 173	+ 420	......	......
1705	2815	1247	1160	218	7145
......	......	+ 268·8	— 268·8		......
1705	2815	1515·8	1109·1		7145
......	— 615	+ 615	......		......
1705	2200	2130·8	1109·1		7145
23·8	30·8	30·0	15·4		100

The deductions from these figures and those that we have got from the investigation of the proportions are—that maintenance at Rs. 1,705 represents the whole cost of maintaining a line, costing Rs. 17,000 a mile, including permanent way material. As it was not in full work, the percentage of this item to work done is naturally higher than 20.

The maintenance figures, however, include all the miscellaneous repairs exclusive of repairs to the permanent way. The deterioration of rails is not fully included, and as no railways have been worked enough to cause extensive renewals to have been made, an excess may be counted on for the future; but again, while lines have been open only a few years, a good many real improvements of the permanent way and other appliances are often done out of revenue, so that the charges on this account are higher. On the whole, it is probable that the sum of the maintenance of rails and ballast, &c., will give a very fair average for both classes of renewals.

Rs. 2,200 or 30·8 per cent. represents the fuel, grease, oil, &c., and repairs to engines and vehicles. The proportion due to fuel must have been as 20; grease, oil, &c., 5; and repairs 10; and the amount of each, dividiug 30·8 in this proportion, would therefore be—fuel 17·6, grease 4·3, repairs 8·9; with the line in *full work* the proportion would have been 20, 5, and 10.

Traffic figures Rs. 2,130, include traffic stores which form 5 per cent. of the whole working charges or one-fourth of this particular item; this being deducted would give the train and station staff at 30·0 — 7·6 = 22·4 per cent.

General Charges—Rs. 1109·1 require the addition of the above stores = 7·6 per cent., making 15·4 + 7·6 or 23·0 per cent.; now add in the locomotive stores of grease, oil, and water, and we get 23·0 + 4·3 = 27·3.

The depreciation of rails in the maintenance must be the same as that in the rolling stock 8·9 (Art. 35), and this being deducted we finally get the following proportions for the whole revenue expenditure:—

			Proportion for Line in full Work.
Train and Station Staff		22·4	20
Repairs to Stock and Rails— 8·9 × 2		17·8	20
Fuel		17·5	20
Maintenance— 23·8 — 8·9		15·0	10
General, &c., &c.— Stores	11·9	27·3	10 } 30
Establishment	15·4		20
		100	

(*b*) The *train and station staff* appears to be higher than the proper proportion for the line in full work, being 11·2 per cent. This is to be accounted for by the unfortunate inclusion of large charges for collection and delivery of goods, which have nothing to do with the train working. In the G. I. P. accounts they make a total of 4,38,587 for the year 1871, being about 10 per cent. on the total traffic charges corrected as above, and amounting to about 43¼ lacs, including Police, Electric Telegraph, and driving charges.

Deducting 10 per cent. of the train and station staff charges would make the proportion 22·4 — 2·24 or 20·16. Station staff will probably be in excess till the line is in full work.

Repairs to stock and rails are in remarkable agreement with the *fuel* consumption; both will somewhat accurately indicate the work done.

Maintenance is higher, while nearly all the other proportions are lower than they would be with the line in full work. This is to be expected; both this item and station staff will probably be in excess till the line is working up to the full power, but as stated above, some of the maintenance is properly chargeable to other heads.

General, &c.—Of these the administration charges should be 10 per cent., and the stores for trains, stations, and locomotive another 10 per cent., leaving 5 for miscellaneous contingencies.

The only one not easily accessible for confirmation is the last. The administration charges are Rs. 860, including the

heads of departments other than engineering, being a trifle over the proportion due on the capital cost; the stores shown are at 11·9 per cent. It is interesting to note that the fuel consumption for the line costing Rs. 17,000 a mile when in full work, being one-fifth of Rs. 8,500 = 1,750, and the fuel consumption on Indian lines 17·5 per cent. of Rs. 7,145, or Rs. 1,250, these railways must have done work to the extent of about 73 per cent. of their full power. (Art. 45 *b*.)*

Also maintenance other than rails *apparently* formed 14·6 per cent. of 7,246 = Rs. 1,058 instead of Rs. 850 per mile, partly owing to the above deficiency of work, *apparently* 24 per cent. in excess. But as this description of maintenance forms only 10 per cent. of the whole working, the excess on this account does not amount to more than 2½ per cent. on the whole working expenses as they now stand.

This somewhat tallies with the proportion due to maintenance out of the total excess of 11·4 per cent. referred to in section (*a*) of this Art.; for all the fixed charges to be equally affected the excess would be 2½ × 5 = 12½ per cent. This would disappear directly the line was in full work.

49. English Railway Expenditure for 1863.

Maintenance	£ 2,847,287	
Locomotive	4,150,499	5,552,855
Vehicles	1,402,356	
Traffic	4,196,122	
Rates, Taxes, &c.	631,127	
Government Duty	395,234	
Compensation	179,565	
Goods do.	68,242	
Law	194,782	
Miscellaneous	962,020	
	15,027,234	
Net profits	16,048,931	
Total receipts	31,076,165	

* It appears from Art. 45 *b* that the lines have done more work than they get credit for in the receipts; this we know to be the case. (See Art. 62.)

Expenditure, 48 per cent. of receipts.

Take first the locomotive and vehicles. As there are no other heads of account, the following must be included in the sum of £5,552,855, and according to ascertained proportions they will be about as follows:—

		£
Fuel	20	3,001,600
Water, Grease, Oil (proportion)	2	300,160
Wages, Driving (Train Staff)	5	750,400
Repairs, Stock	10	1,500,800

Grease, water, oil, &c., for the whole of the trains forms 5 per cent.; the remainder is most possibly charged in the traffic department for greasing vehicles, &c.; 5 per cent. is also due for traffic stores irrespective of this, for trains and stations, so the whole will be represented by 8 per cent. in the traffic amount.

The other proportions will include the guards and brakes men of trains 5 per cent., stations 10 per cent., and administration. Now of this last the Locomotive Superintendents and Traffic Managers and their departments haye in every probability been included in their own departments. They may be allowed 1½ per cent. on the total working expenses in each of those departments for this, or 3 per cent. altogether, giving the proportions of the sum of £4,196,122 for the traffic heading in round figures—

		£
Part of Train Staff	5	700,000
Station do.	10	1,400,000
Stores (traffic and greasing vehicles)	8	1,120,000
Administration	7	980,000

Arranging this rough classification, and assuming that maintenance was half for rails and half for other materials, we get—

Maintenance—		£	
Rails		1,423,643	
All other		1,423,643	
Locomotive—			
Fuel		2,879,600*	
Rolling Stock		1,439,800*	
Train Staff—			
	720,200* 700,000	1,420,200	
Station Staff		1,400,000	
Stores—			
	1,120,000 257,960*	1,407,960	Items marked* are *less* administration charges.
Administration—			
3 per cent. of working	980,000 450,816†	1,430,816	†Sum of deductions marked with the asterisk.
Miscellaneous—(Balance)		2,201,572	

Without knowing the nature of the charges included in the last, it is impossible to account for the large proportion.

It is highly probable that a very large portion of the charge, £962,020, partly composing it, is for collection and delivery of goods for which there appears to be no other heading to which it could be booked. Also there may be charges connected with the interchange of traffic which are not analyzable.

If a deduction of £778,000‡ was made from the last item £2,201,572, leaving it standing at £1,423,572, the probable proportion due on actual railway operations would possibly be fairly represented. But leaving out this item, which is a general one, we cannot but remark the apparent coincidence of the totals of the different classes with the proportions ascertained by the foregoing inquiry.

One thing requires notice; vehicles alone are represented to have cost £1,402,316 to repair, while the whole repair including engines is now represented to be £1,439,800. This may be

‡ Assuming this to be wholly for collection and delivery, the amount is about 5 per cent. on the *bonâ fide* railway gross charges.

explained by the fact that all such heads of account have had greasing, administration, and carriage cleaning included generally, and it is probable the accounts of English Railways are no exception; it will be remembered they form no less than half as much as the repair of the whole rolling stock.

The average rate of dividend is given by the author* of the book from which the above data are taken at 4·16 per cent.

The percentage of expenditure to receipts is given at 48, being a million under that due to equality. Having in view the large expenditure on 'Miscellaneous' referred to above, the idea suggests itself that the excess of receipts is due partially to operations distinct from railway *bonâ fide* earnings, possibly taking the form of "terminals."

AMERICAN RAILWAYS.

50. '*Engineering*' for 3rd April 1868, has the following interesting notice headed 'American Railways.'

"The State of Massachusets, 7,250 square miles in extent, and having a population of about a million, has 1,612 miles of railway, of which but one-third is double line. These lines have cost £11,000 per mile. Last year the working showed the following figures :—

		Train Miles.
Passengers carried…………	22,928,392	5,007,199
Tons of Goods ……………	5,843,096	4,268,901
Receipts per train mile……	7*s*. 9¾*d*.	
Expenses …………………	5*s*. 9*d*. or 70 per cent.	

Nett return on cost of lines, 6 per cent.

Average divided by dividend paying companies, 8 per cent.

Working expenses—

Repairs of way…	300 £ per mile, or 12·4*d*.	per train mile.
Fuel……………	9·3	,,
Engine Repairs.	6·2	,,
Carriage & Waggon Repairs…	6·55	,,

* William Chambers.

There were 9·2 trains each way daily over the whole length.
Paying freights per train—

Passengers	69·8 (number.)
Goods	53·4 (tons)
Average Passenger fare..................	1·12*d.* per mile.
Goods do.	1·84*d.* per ton mile.

There is only one class for passengers."

This is an interesting case of cheap lines apparently earning a large rate of net return.

The receipts by a railway or any other company are rather an indication of the ability and willingness of the customers to pay, than of the performance of the works.

It appears that the passenger fares are at least four times the Indian 3rd class, and the goods about 30 per cent. higher. The Indian 5′ 6″ lines have cost about 50 per cent. more per mile. The gauge of the lines in Massachusets is not stated, (it is most likely 4′ 8½″). It appears to have had full work, so the working expenses are not high through deficiency of traffic; it is more than probable there is a large excess of work.

This view is confirmed by the fuel consumption. The current rate of profit could not be known without the price of the shares in the market being stated. It is possible that the premium would reduce the dividend to the ordinary 5 per cent., if not lower. The fuel cost 9·3*d.* per train mile, and there were 9·2 trains daily both ways, giving £1·7825 for the daily working expense in one direction, reckoning it at five times the fuel expense; and for 313 working days given in the notice the total working expense per annum would be £557·92 : now this capitalised at 5 per cent. gives £11,158 per mile for the cost of the railway, which agrees as nearly as possible with the reported cost, showing that, as the amount of traffic was double this, *i.e.*, 9·2 trains *each* way, the line was made to do about double the work due to the capital.

This gives a clue to the large proportion of working expenses. It will also be seen that there is a large excess of engines and

vehicle repairs (12·75*d.*) with a heavy excess (12·4*d.*) in repairs of the way, the cost of the fuel being 9·3*d.* per train mile.

The proportions for the cost of fuel to be 9·3*d.* should be 4·65*d.* for engines and vehicles each and 9·3*d.* for permanent way, showing that there was 2·74 times too much spent on the former and 1·33 times too much on the latter.

Again, if the net earnings of a machine, being 30 per cent. only, represent 6 per cent. on the capital, the working expense represented by 70 must be equal to 2·33 times as much, or 13·98 per cent., which indicates usually that the machine will only last 7·16 years.

From all this it is gathered that the working expenses are so high owing to the lines being constructed with insufficient durability and perhaps on too small a scale for the traffic carried in 1868. The engines and vehicles may have been too small or lightly constructed, the gauge too narrow, or gradients too steep, and weight of rail too little, or an insufficient length of line may have been doubled.

In order to reduce the working expenses to 50 per cent. of the receipts they ought to be reduced 32 per cent.

A net earning of 6 per cent. seems a high one, for which it might be said the smallness of the capital should get the credit. On the contrary, however, the smallness may prevent a larger net profit from the same traffic and rates when the working expenses are so high, if capital is procurable cheaper, as will be evident from the following.

An increase to the capital spent in producing more durable stock, permanent way, &c., will prolong the life, and make the yearly cost of renewal less, while truly the addition to the capital reduces the net profit.

If the amount of durability given by the increased capital expenditure exceeds the amount of the loss of net profit for the additional capital, it is clear that the net profits on the whole will be increased.

Now since in the case of renewals or working expenses being 14 per cent. while fresh capital can be got at 5, it is

evident that the durability, which is as the quantity of labour and material, will be as $\frac{1\cdot4}{\cdot5}$ or 2·8, while the interest liability is only as 1·0. Thus an increase to capital represented by an interest 1 will produce a corresponding working expense $\frac{1}{2\cdot8} =$ ·33. This is the same thing as a capital interest of ·33 causing a corresponding working expense $= 1$.

Since the saving in working is more than the interest on the additional capital, it clearly will lead to increased dividend to spend more capital wherever the working expenses exceed the rate of interest, which brings us back to the starting point, viz., the proposition that interest on capital and working expenses should be equal.

If money is not to be got at less than 14 per cent., it would be no good to invest more in the case now noted. It is highly probable that high profits, and the difficulty of obtaining money in a rapidly rising country on private account, may render cheap construction and high working expense expedient, but it must always lay the country under the disadvantage of high rates of carriage, and is not a system at all necessarily to be transferred to one where money is cheap and the mass of the population poor.

With regard to the large cost of the renewals of way and rolling stock noted above, it will be seen by referring to Vol. XXVII. of the Civil Engineers' Institution Proceedings, that Mr. Z. Colburn, in his valuable paper on American Rolling Stock, states, page 382, that the carriage and wagon stock in these very States, in 1867, cost 2½*d.* per train mile, which puts it at nearly the figure proper for the fuel consumption, or half that due for engines and vehicles (4·65*d.*) This leads to the inference that there must be some mistake in the cost for the lines in 1868. Captain Tyler, in the discussion which followed, also remarked, page 412, that the cost of engine repairs was 6·83 cents or 3·41*d.*, which confirms the inference.* He also men-

* It is possible that greasing, cleaning, &c., have been included in repairs in the figures given in *Engineering*.

tioned that train loads were very much heavier in America than in England. The last circumstance would have to be well borne in mind in any comparison of working referred to the train mile, for it is evident that the same quantity of traffic would be conveyed in a smaller number of trains of greater cost each. It would account also partly for the apparent discrepancy between permanent way, and stock repairs.

It is a great pity that the comparison by the ton mile is not possible owing to the absence of registers; it would give perfectly accurate and reliable data for basing conclusions on whatever the gauges and train weights might be.

The dead weights per passenger are given by Mr. Lloyd at

	1st	2nd	3rd	Goods, per ton.
American............	422	390	375 lbs.	1,406
English	522	327	298 lbs.	1,500

these being for the 5′ 6″ gauge.

The cost per train mile is given at,

	American, 1855.	England, 1856.
Wages, Engineman & Stokers.	2·70*d.*	1·62*d.*
Coal, Coke	8·95*d.*	3·25*d.*
Repairs of Engines	4·90*d.*	2·75*d.*
Do. Cars and Wagons	4·35*d.*	3·75*d.*

It is hardly possible to compare the items with the meagre classification of expenditure available, but it is highly probable that grease, water, oil, carriage cleaners, fuelling, &c., are included as repairs; these form as great an expense as either the repairs to vehicles or engines (Art. 35), or about 5 per cent. of the expenditure, and assuming this to be the case, the *bonâ fide* repairs would be about 3·08*d.* for engines and vehicles on the average in American, against 2·17*d.* in English railways, which would bring the proportions nearer to those assumed as correct for American railways and nearer to Mr. Colburn's and Capt. Tyler's estimate of the repairs to the vehicles. As for the figures for English railways, they appear out of all harmony or the usual proportion.

The above is intended amongst other things to show how difficult it is to ascertain the most important details of railway expenditure, owing to the want of a little uniformity in the classification of accounts and registration of the ton mileage.

MAURITIUS RAILWAY, 4′ 8½″ GAUGE, COST £21,876 A MILE.

Mr. James R. Mosse, in his paper on the above, read at the Institution on February 2, 1869, shows that the expenses in the Locomotive Department were,

		d.
Fuel, per mile		10·90
Oil, tallow, waste		1·20
Materials for repairs of engines	2·08	
Carriages and wagons	1·84	
		3·92
Salaries of Superintendent, Drivers, Firemen, and Cleaners		6·19
Do. Mechanics, repairing Engines	2·57	
Vehicles	1·40	
		3·97
		26·18
Consumption of fuel per mile run		49·7 lbs.

The gradients on this line are very heavy, and trains consist of an engine of 37 to 48 tons, and but 5 or 6 wagons, giving certainly not above 90 to 100 tons per total train weight for nearly 50 lbs. of good coal. This large expenditure of coal, about ·5 lbs. per ton mile, 2½ times that used on the level, will account for the large working expense of the line.

BRANCH RAILWAYS.

51. A railway without branches is like a main drain without sewers. It has all the capacity for carrying the floods of a great district, while it catches only the surface water of the immediate neighbourhood. The construction of branch lines is in every way desirable for the main lines, while the branches confer benefits on the localities. But there has always been a

certain hindrance to the progress of branch lines in the short-sighted policy of the managers of original lines in not only not offering sufficient inducement to capitalists to embark their money in that direction, but often placing obstacles in the way for some supposed or real advantage to a particular undertaking. However much such a system may benefit individuals, it is quite against the interest of the public, and sooner or later leads to competing lines and waste of capital.

One of the leading causes of sluggishness in constructing branches is certainly the difficulty of apportioning the first profits to each undertaking during the infancy of the new branches, and at the same time giving the maximum stimulus to production and trade by quoting the lowest through rates. It is quite certain that a short branch in the matter of through traffic does not at first receive the same benefit for its capital invested as the main line, if it is much longer; but to show this it is necessary to touch on the traffic management. In Art. 44 (*i*) rates were exhibited which we may adopt for the sake of an example as those at which the lines already constructed in India could afford to carry at the present time. These rates would be liable to alteration from time to time, and would slightly differ according to the circumstances of every line; but whatever they are, there is no difficulty in fixing the chief proportions and the actual cost for every line, every train, and every portion of the road if need be. They do not include interest on excess capital invested for the actual amount of traffic offering, or excess of fixed charges:—

	Train cost.	Train cost including agency general, &c.	Whole cost including interest, & working expenses.	Total including maximum excess balance of traffic.
		× 2	× 2	× 1·5
6th...	7·625	15·250	30·500	45·075
5th...	3·105	6·208	12·416	18·624
4th...	2·371	4·742	9·484	14·226
3rd...	2·000	4·000	8·000	12·800
2nd..	1·776	3·552	7·104	10·656
1st...	1·602	3·204	6·408	9·612
Average	2·21	4·42	8·84	13·26

Diminished Rates for special purposes.

(*a*) It may be remarked that half as much again has to be added to the rates to cover the maximum expense of empty haulage, but suppose circumstances, or a set of the traffic, change the direction to equality during a certain period, or for a constancy, it is evident that while this is the case, the profits are doubled as long as the previous rate is charged. Advantage may frequently be taken in this respect, when the course of traffic is ascertained for different seasons to make rates lower (if they will attract new produce) than would be politic at other seasons. The ordinary rate of six times the net train cost may, for such purposes, be made only four times the net train cost, at the judgment of the traffic department.

It appears that in order for the work performed to get its share of interest on capital, it is necessary to make the rate four times the net train rate under ordinary circumstances; but suppose that goods would offer, if they could be carried for less which are unable to bear the carriage! Since the actual cost, excepting interest on capital, is only twice the net cost of the train, leaving twice the net cost to represent the interest on the capital (at 5 per cent.), would it not be better to carry at anything over twice the net cost of the train, and earn anything between 1 and 5 per cent. that the goods can contribute, rather than nothing, *if the line is not in full work and can carry it.*

Proceeding even further, and supposing the line *not in full work*, (and therefore most possibly not earning the guarantee,) considering that some charges for agency, general, maintenance, &c., must be incurred even though only a single train were run, would it not be advantageous to earn anything towards the payment of these expenses by carrying at anything between the net cost of a train and its double?

It is quite clear that according to circumstances it can be possible, and may be politic to take traffic at anything between the net cost of a train and six times the sum.

The cost of transporting a ton of cotton a mile by country cart is as near as possible 20 pies a ton, which allows a man

with a pair of bullocks travelling 6 miles (12 miles with half a ton) a day to earn 10 annas. This is a low rate, but it is actually done in the slack season from Sholapore to Bombay, 233 miles. The carts are sure of a return freight of salt, not anything like all of which is carried by the G. I. P. Railway.

It will be quite plain that the railways can with ease run off the line any traffic going by competing routes. A bold policy which would once for all shut up an old trade route would leave the railway free to get its just rates afterwards and monopolise the whole traffic.

At this moment it is patent that thousands of carts of goods find their way down and up the 2,000 feet ghauts alongside the railway, owing to the rates charged by the railways being *three times* the ordinary rate per mile obtaining on the main *line*.

The ghaut expense, whatever it may have been, is an integral part of the whole line. It drains no area of production, but it is as necessary to the whole undertaking as any bridge, viaduct, or other portion of the line. The average rates, whatever they may be, should apply equally to every part of the line, the extra cost, from the necessity of the ghaut working, entering into the composition.

The rates before quoted have been arrived at, after taking in the cost of the ghauts, in the general cost of £17,000 a mile.

Having indicated the direction in which to look to see what can best be done to ensure all the traffic coming on to a new line, and how to ascertain the rates which may best remunerate the undertaking, it is necessary to ascertain what is due to the customers for the traffic they contribute.

(*b*) It is to be expected that the person who contributes most earnings to the company should in some manner be encouraged, above the merchant who contributes very little.

The earnings may be contributed either by a large quantity of goods over a short mileage, or a smaller quantity of goods over a longer mileage.

It has been the custom occasionally to allow drawback to consignees of large quantities; but there are objections to the

practice, such as the combination of trade agents to lump the existing traffic into large consignments simply to get the drawback. Instances have been known where, owing to the system of drawback, goods have been diverted from a foreign company by a country trade route to the junction of the other line for this purpose. Owing to there being no drawback arrangement on the foreign line or mutual benefit from the system of through booking, traffic was on the whole actually lost to the State, besides the amount for drawback being a tax on the consumer; drawback for *quantity* therefore requires great care in the management.

Reduced rates for *distance* are of universal application, and no objection can be raised to the system.

Diminished rate for distance.

(*c*) Seeing the large reductions which it is possible to make, as before pointed out, to suit every contingency of the trade, it is quite clear that the greatest advantage to the railway and the country will be when the rates for carriage are progressively and regularly diminished for distance, as long as any augmentation of the revenue can occur which, *minus* the expense, leaves any profit.

As long therefore as an acre of ground able to be cultivated, or a man within decent range of the influence of the railway able to be carried, is left out, the railway is not doing all the work it was designed for, or is capable of extension for doing.

Since the cost of carriage of the goods has to be added to the cost of production, it is evident that, in order for more land to be brought under cultivation, the producer at a distance must be put on somewhat equal footing with others nearer the markets, so that he may realise the common prices.

Rates which have not therefore the principle of reduction for long distances cannot apparently be successful in all cases of lines in new districts.

Under ordinary circumstances it appears that the average goods rate ruling is about 13·26 pies.

From what has been said it will be perceived, that half this rate is the working expense and half the profit (proportion of interest). Anything above half will therefore pay something.

(*d*) Profit is the realisation over and above the expense in a certain time. Whatever it may be, it will be evident that if double the quantity be carried, or the distance for the same quantity be double, within the same time, the expense per ton mile remaining the same, the *capital* has earned double the profit in the time.

Profit.

Thus within the year the guarantee may be earned, although some portion of the goods may have earned on a portion of the line, much less than their fair share of it.

The politic limit evidently lies between double the full rate and half the rate at which we arrived, under ordinary circumstances, to start with, which includes every possible expense and varying rates of profit.

Much will of course depend on the state of the markets in regard to the prices produce will realise and carriage they will bear at any time, but the principle of reduction of rates for long distances is unaffected by this.

Through reduced rates are no doubt called for, to suit the state of trade or peculiarity of any particular commodity and to overcome competition; but these conditions are apart from the question of reduction for distance which is essentially to stimulate production.

The traffic on a line should increase as the area of productive country brought within the influence of the railway.

A line fed by sufficiently developed branches will have a traffic at any one point increasing as the square of the length, while one without branches increases only as the length at any one point.

A branch without subsidiary branches will be in the same position as a main line without branches: thus while the last, say the third, laminæ of a complete system of railways will only drain country in proportion to the length of lines, the secondary

and primary will draw a traffic in proportion to the square of their length. When the branches have been fully developed they will draw as much traffic per mile as the main line, and the through traffic of the main line may be doubled.

This seems to indicate that the capital employed in branches should equal that laid out in original lines.

(*e*) It is clear that either branches are required (and may attract double traffic), or they are not. If they *are*, then it must be conceded that they are to bring a traffic which does not and cannot exist without them.

Since the capital embarked in branches should equal that employed in the main line, it is evident that principal branches may be made first equal in total cost to the total cost of the single line of the main trunk, that other branches may afterwards be made, and the necessity arise for more capital expenditure on the main line, without altering the relative proportions of capital expenditure.

Thus it will be seen, till the branches have developed subsidiary feeders and new areas of cultivation, they must labour under great disadvantages in regard to the return of interest on capital, compared to the existing line, to which they are feeders; while ground is only partially cultivated sufficient produce cannot be forthcoming to send away, or manufactured goods of course return.

Again, as long as there is only a short length of a branch feeding a long length of main line, whatever traffic is contributed by the former to the latter would probably travel over so much longer a mileage, that the proportion of profit in the same ton of goods would be very much greater on the latter undertaking in the time. Allowing that the traffic brought by the branch is due to the capital invested in the branch, it seems that a certain amount of consideration is due from the main line to the branches for the capital used, in bringing new traffic over and above what is due on a mere mileage division of a through rate.

It is acknowledged that through rates for distance are indis-

pensable for all traffic. Yet it would be a manifest injury to a short branch joining the main line at a long distance from the great markets, to give it only the mileage proportion of a diminished through rate, when it derives no advantage from the increased profit to the main line.

The diminished rate is applicable to the long line as far as the junction, but the branch made on a separate capital owes nothing to the producer of traffic beyond that junction who does not contribute to increase its profits in the year. The branch can certainly afford to carry an *equal* mileage at through rates for the convenience of both concerns, but it cannot submit to give up its local rates beyond this extent without injury. Through rates, as have been shown, are highly desirable, but the only just reason why the branches should abandon their local rates with an excess mileage of the same goods booked on to and from the trunk line, would be in consideration of some portion of the excess profits earned on them by the trunk line through the difference of long mileage.

(*f*) It therefore suggests itself that with a view of encouraging the rapid growth of branches, the parent line should allow a percentage on the difference of mileage occurring in the through booking in proportion to the capital invested in the branch with respect to its own capital.

Through Traffic.

This would have the effect of stimulating the investment of capital in branches, and as the open mileage of them increased, so it is presumed would the traffic along with the capital sunk. While the proportion per cent. of the "difference of through mileage' given by the main line to the branch would increase continually as the capital proportion of the branch, yet with the mileage resulting from the opening up of the lines, the "difference of through mileage" would continually tend to disappear till the expenditure on the branches having become equal, and the traffic equal, the mileage "percentage on difference" would altogether disappear.

Thus through receipts would in the first instance be divided

according to the mileage on each line, and then the difference having been ascertained at the end of the half-year, a deduction would be made for the branch from the excess earnings on the traffic mutually interchanged in proportion to its capital, till construction had been stimulated to the utmost and the capitals were equal, when the receipts would be divided in the proportion of the mileage simply. Should the branch, by any turn of fortune or trade, enlarge so as ever to become the main line in magnitude compared with the parent line, it could afford a similar amount of the encouragement to the original line.

It seems that a system such as this would give unity of action and support, where otherwise opposition and waste of power would occur, and there also appears to be no limit to the power of application of the principle to facilitate combined action of independent railways.

As regards the diminished rates while lines are not completely developed, it is clear that when they are once working at their maximum all over, there can be no diminution of the mileage rate for any cause whatever, except stimulation of further production and construction of new lines or doubling the old; but as the development proceeds, the rates near the markets will be reduced, while the rates at more distant parts will increase as local markets spring up, till equality exists all over the lines, when equal development has occurred. Should development still press for more accommodation, it will be advisable to spend more capital in gradually doubling the lines, working on the uniform lowest mileage rates, just paying for the expense incurred, including the return of the rate of interest on the capital. Anything less than this would manifestly be working at a loss.

All that has been said tends to show that low rates are likely to be more effective in rapidly developing the traffic than high, and favors the proposition to make the rates solely with reference to cost of carriage and some regard to distance.

In making reductions of charges for attracting additional or new traffic, it must be borne in mind, that the reduced rate will

probably apply to the quantity of the same commodity already carried. In order to earn the same receipts therefore with a larger quantity, this must be taken into consideration. For increasing quantities or mileage in the same time the rates would be as seen in the following—

*Example.**

Tons.	Cost.	Profit.	Rate per ton.
1	6·66	6·63	13·26
2	13·26	6·63	9·89
3	19·89	6·63	8·84
4	26·52	6·63	8·29
&c.	&c.	&c.	&c.
Limit	......	......	...... 6·63

As far as the State and public interests are concerned, the rates so arrived at would be advantageous. In the case of a company they would fairly claim to divide the profit arising from extra quantity with the customers by taking the average of the former and new rates. It would of course not pay a company to make a reduction due to double the existing traffic, if less than that quantity was likely to be received, without they had some other special object in view, such as removing competition and stimulating production.

MISCELLANEOUS.

Break of Gauge.

52. Since the object of railways is to open up the country, if it is equally eligible for development all over, the ultimate requirements will be the same. This would indicate a uniform gauge for a uniform traffic. It would also avoid transfer of the goods from one wagon to another.

But if the country is not equally promising, it may be advantageous to use railways of less cost for the smaller traffic likely to be carried.

The larger the system of railways is likely to become, the greater the inconvenience from break of gauge, owing to the

* It will be observed that the most rapid reduction is for double the quantity.

large quantity of goods to be frequently transferred, and it then becomes a question, leaving out the subject of competition between companies, whether it is better to capitalise a little in advance of the requirements of the immediate traffic offering, to obviate it.

From what has been said of the cost of carriage it will have become evident, that in railways whose gauges are exactly suited to their traffic, they can all carry at equal rates, including the return of the same interest on the capital.

If we design a narrow gauge to exactly suit its traffic, the charges on the ton of goods on that line should be the same as on the other gauge to which it is a feeder.

The incidence of charge for transferring the load is in that case a tax on the whole traffic, and one that will press more on the producers near the junction than those further off, because the transfer charge will form so much less a proportion of the mileage rate for those distant from the junction, than when the mileage of the goods is short (as it will be) in the neighbourhood of the junction. This will have a varied effect on different traffic, but the tendency will be to divert goods coming from the surrounding neighbourhood to the junction to escape the transfer charge, if it appears at all in the rates, or if it does not, the loss must fall on the working of the lines.

Goods once in a cart on their way to a railway station could as easily travel the complete day's journey as half or quarter, and would probably cost no more, and there is no doubt that owing to slack seasons of agricultural operations there are always times when the cultivators can use their bullocks for traffic at rates which will compete most effectually with the full railway rates.

This applies to deliveries of goods at all stations, but it does not seem too much to assume that the traffic for 15 or 20 miles will carefully avoid any obstruction like an increased rate, however small the increase may be.

Deficit of Receipts.

Since there is only one maximum effect to be got out of a capital invested in a machine, and that is when the machine is exactly suited

to the work it has to do, if the work exceeds, it is clear that to perform any extra quantity we must invest more capital. This may be a gradual process in many cases, such as the opening of a new station on an existing railway, &c., but when you come to increase the capabilities of the line for a completely extended traffic, such as doubling the line, it is almost impossible to expend capital in exact proportion to the work to be done immediately, and there must consequently always be a deficit of railway receipts in a large system, which is constantly extending in some direction or another, if the rates are calculated on the cost of carriage, including only the equitable share of capital interest and fixed charges for the existing traffic.

Thus it seems that a narrow gauge system equally with all others is liable to a debt for interest wherever there is either a traffic too small for the railways, or one extending beyond the capabilities of the lines. The latter being a certain sign of progress, can hardly be considered an unsatisfactory state of affairs; the former diminishes every year, as development proceeds. A narrow gauge is not therefore necessarily a specific for deficient revenue, but assuming it to be required, let us see what extra expense is involved by the break of gauge.

The actual cost of transfer of a ton of goods is not much, perhaps 4 annas a ton would cover it. There are, however, other considerations which must not be lost sight of, and they are the absorption of capital in the trains and sidings required to be idle from both lines at the junctions.

For instance, suppose the existing traffic of the present railways (5′ 6″) to be 100,000 tons per annum all over the lines, and that by constructing a system of 3′ 3″ gauge feeders to cost £6,182, this traffic may be doubled. It has appeared that the capital sunk in branches should equal that in the *main* line.

The cost of transferring 100,000 tons at 4 annas a ton= Rs. 25,000, the actual cooly labour. Retention of trains, of wagons and engines on each gauge equivalent to one train on

the 5′ 6″ at the point of junction constantly, the same being absorbed from the general stock for that purpose.

		Value of Trains.
Broad gauge........................	Rs.	83,000
Narrow do. (2 trains)	„	83,000
	Rs.	1,66,000

To this has to be added the sidings, permanent way, and terminal arrangements for transference of the loads, making about a quarter and half a mile of line on each gauge respectively at least.

The cost of this will be—

Broad gauge......	Rs.	42,500
Narrow do.	„	30,910
	Rs.	73,410
	Add	1,66,000 for trains.

2,39,410 Total = the cost of four miles of narrow gauge for every train transfer. Now if goods are all conveyed to the great terminal stations, they will only require one transfer, but all goods going from one branch to another will require two. A break of gauge in a trunk system of lines will require two transfers for every break. The trains and sidings will all be required for such.

In a system of 600 miles of trunk line there will be probably 5 junctions. The plant required will be for 5 trains = Rs. 2,39,410 × 5 = Rs. 11,97,050; taking one-half of the branch line traffic to be from one branch to another, there will be two transfers of this traffic = 25,000 Rs., and reckoning that half the main line traffic may be eventually subject to break of gauge, the amount before put down may be found to amount to 43,250 Rs. over a complete system of, say, 600 miles of main line (to Central India).

To this add $\frac{1}{10}$th of 11,97,050 Rs., the earning due to the capital sunk in junction arrangements and their working, and

the total becomes Rs. 1,62,955 or 1·63 Rs. a ton. This equals the cost of carriage of a ton over 24 miles. The length of a narrow gauge system for a trunk of 600 miles would be $\frac{17,000}{6,182} = 2\frac{3}{4}$ as long * = 1,650 miles.

The cost of transfer, unless there were many changes of routes, can hardly be considered vastly important, but with every transfer the amount would be increased, and in a populous country like England, possibly four or five changes would be required in a mixed gauge system.

TERMINALS.

53. It has been the custom to charge terminals, or a fixed amount for every ton of goods with some exceptions brought on to the railway ostensibly with a view of meeting the expense of the loading and unloading, on receipt and delivery of goods. Such charges are inevitably necessary to enable the business of the railway as carriers to go on at all, and are purely station staff charges, provided for and necessary to work, the capital sunk in the station or terminal premises. These terminals, like those mentioned in the last Art. press heavily on freights travelling short distances, and tend to divert traffic.† They do not encourage the use of the railway and especially for short distances, and are a clear tax on all production. Cartage charges for delivery of goods, or any other special convenience for the public, are of course perfectly fair, if they are quite distinct from the railway service, and the companies can undertake them with a view of encouraging the use of their lines.

The tenacity with which companies stick to the impost of these charges goes far to show the apparently *easily* earned profit they are to railways. It is not at all clear that the total abolition of all but cartage, would not be attended with increased profits from the legitimate sources, viz., the train receipts. The accounts for terminal charges should be quite distinct.

* Some of this will no doubt be double line, if not all, and some may be trebled.—See table of cost of gauges.

† See note on page 129.

Comparison of English and Indian Railways.

English and Indian Railways.

54. Mr. William Chambers, in his little book 'About Railways,' informs us that the average cost of English Railways was up to 1862 about £35,000 a mile including rolling stock, that the Parliamentary expenses for some of the lines were as under per mile :—

	£
Brighton	4,806
Manchester and Birmingham	5,190
Blackwall	14,414

That the ordinary expense of a double line was, for *construction* only, about £12,000. That the rates were per mile :—

1st Class, ordinary	....	2½*d.*
2nd do. do.	....	1¾*d.*
3rd do. do.	....	1*d.*, 1½*d.*

That the expenses according to Board of Trade returns of 1864 were £15,027,234 (see analysis, Art. 49).

Train Mileage—Passengers. 61,032,143 miles.
Do. do. —Goods...... 55,560,018 do.

Taking the passenger trains at half the weight of the goods, and the latter to weigh 220 tons each (*i. e.*, proportional to the gauge, 260 tons being the weight of the Indian trains) the total expense per ton hauled would be $\frac{\text{£ } 15{,}027{,}234 \times 12 \times 20}{\text{miles } 86{,}076{,}089 \times 220 \text{ tons.}} = \cdot 1904$ of a penny per mile.

Thus the comparative cost of a ton of gross load, one mile, would appear to be, at 8 pies to the penny = 1·5232 pies in England against 1·4280 pies on the Bombay railways, supposing them to be in full work. The fares would compare as below :—

	At Bombay. Pies.	England. Pies.
1st	16	20
2nd	8	14
3rd	3	10

Therefore, while the cost of haulage in England is a fraction above that incurred in this country,* the fares are very

* Art. 47 *d.*

much higher, and the great paying class, viz., the 3rd, is more than three times that charged on Indian lines.

These facts seem to point out that since the Railways did not earn more than 4·16 per cent. in that year the fares are so much higher on account of the vast expense of the undertakings, apart from the actual cost of construction, which has raised the capital account to double the rate per mile of the Indian railways. It is necessary for the interest to be recovered on the excess capital, hence higher rates must be charged.

It is worthy of note that the fares in England for the three classes do not differ so much as in India, the 1st class being only double the 3rd, while in India it is more than five times as much.

The difference also between 2nd and 3rd is only 40 per cent. of the former, while in India the 2nd is more than double the 3rd.

The upper classes are proportionally much higher in India, and since the high fares tend to the running of comparatively empty vehicles, they are a source of loss, which would be very much mitigated with less differences in the rates of classes.

The high fares in England are a burden imposed by the British public on themselves, apparently by the unlimited system of private enterprise; it is hard to see how it could have occurred, had the lines been constructed by the State, or with powers for the resumption of lands and properties at a fair valuation, which could only have been wielded by the State. The system has possibly tended to the enrichment of some classes, landowners, lawyers, &c., who can afford the higher fares, but lower class locomotion must be much restricted by the high fares, consequent on the excess capital cost.

As regards the English gauge (4′ 8½″), Mr. Price Williams, in his paper on the maintenance of permanent way, shows that the traffic on lines is so great that the rails have only a life of 3½ years in many cases, and the average does not appear to be above 7 years.

There must, according to this, most possibly be about double the traffic accompanied by its liability to accidents and increased working expenses, absolutely necessary to be screwed

out of the line, in order to repay the interest on excess capital. The gauge is not proportioned to the capital, or the work to be performed; had the same amount of capital been expended with more of it in a broader gauge, and less in law and other exorbitant unremunerative charges, we should perhaps have seen the pleasing spectacle of millions of our poorer fellow-workers constantly taking their holidays and Sundays at the seaside, who are now obliged to content themselves with a risky excursion once a year. The extension of towns would have proceeded much more rapidly, and the needy circumstanced would have been better housed. If it is true that English railway property represents 500 millions, it might also be true that more than half the amount has been unremunerative capital.

The capital employed solely on construction should be the measure of the work possible to be duly performed without strain, and the extension of trade can then be accompanied by increased capital expenditure on new lines, or doubling the old, with every prospect of a healthy state of the dividends.

Directly burdens are imposed that are not distinctly referable to the power required to be exerted, the machine will be tested beyond its strength, and its efficacy will be crippled for ever, for it is impossible to reduce the capital account to improve the dividend, while the accession of additional work through growth of traffic is constantly calling for an increase in it.

Stores Capital.

55. The amount of capital locked up in stores is required to be as small as possible.

The amounts at present for the G. I. P. and B. B. and C. I. Railways are—

G. I. P. £1,484,162
B. B. & C. I. .... „ 570,234,

about $7\frac{1}{2}$ per cent. of the capital. It is clear that this unproductive burden augments the interest charge enormously, and would account for nearly one-third per cent. of the railway guarantee interest deficit. It has been shown before that the

charge for maintenance of the rolling stock and rails is 20 per cent. of the whole working charge, and that the maintenance of the other works forms another 10 per cent. Also coal, grease, oil, &c., form 25 per cent. of the whole working charge, and that all these amounts should represent interest on capital invested at 5 per cent. (Art. 35.)

To take them in detail. The rolling stock and machinery will form 10 per cent., divided equally between vehicles and engines. (Art. 40.)

The stock required to be kept on hand can certainly not be greater at any one time than would represent 2 years' consumption. This would represent $\frac{1}{10}$th of $\frac{1}{20}$th of the capital per annum, or ½ per cent. altogether per annum, or 1 per cent. for 2 years. But materials form 40 per cent. of the whole cost of these repairs according to Mr. Juliand Danvers' reports, and allowing them to be 50 per cent., the actuals for the rolling stock would be:—

Engines	¼
Vehicles	¼
Total.........	½ per cent. of the capital.

Rails will wear out as fast exactly as the rolling stock, but only one year's supply need be kept; the labour of laying these, however, forms but a small part of their final expense,—so that ½ per cent. may be considered a year's supply at the outside.

Sleepers, spikes, keys, &c., will be renewable all the year round, and it is necessary to keep a year's supply. They form about 10 per cent. of the working charge of the year, taking the average of a system of lines. This represents ½ per cent. on the capital; 10 per cent. of the working charges, or ½ per cent. on the capital for maintenance of the whole of the rest of the works, will fairly provide for extraordinary renewals of bridge-work, &c., and tools and plant, when we consider that only half the whole charge for such renewals will probably be for stores.

Thus the amounts will stand :—

Rolling Stock..................................	$\frac{1}{2}$
Rails	$\frac{1}{2}$
Sleepers, Chairs, Spikes	$\frac{1}{2}$
Bridges, &c., Tools, &c.	$\frac{1}{2}$
Coal..	$\frac{1}{2}$
General, Miscellaneous Stores	$\frac{1}{4}$
Total...........	$2\frac{3}{4}$

Regarding the two last,—coal forms one-fifth of the whole working expense or $\frac{1}{100}$, or 1 per cent. of the capital, but it rapidly deteriorates by keeping, and should not be had out more than 6 months before it is used. It would necessitate large sheds to keep large supplies, some of which may be avoided by keeping only 6 monthly supplies, and this gives $\frac{1}{2}$ per cent. on the capital.

General and miscellaneous stores may be provided for traffic at 12 months' intervals (Art. 36*f*). They will be $2\frac{1}{2}$ per cent. for grease and oil, and 5 per cent. for traffic stores, &c., many of which are procurable in this country, and should be bought from current revenue; 5 per cent. would be enough to include on capital account for all these, giving $\frac{1}{4}$ per cent. on the whole capital. The total of $2\frac{3}{4}$ per cent. on the capital will be the same as 55 per cent. of a year's working expenses, which will perhaps be the fairest way of computing the actuals to be maintained as applying exactly to the existing traffic.

Mr. Juliand Danvers shows the working expense for 1871 to have been £3,302,050 for all India. The stores due on this amount, according to the above mode of calculation, should be 55 per cent. or £1,816,127. The G. I. P. and B. B. and C. I. Railway stores alone are a little more than this. Reduction in accordance with the above would make the proportion of interest deficit due to stores considerably less than half what it now is.

Permanent Way Renewal Fund.

56. Amounts due to renewal of vehicles and permanent way are easily determinable from the ton mileage performed

during the half-year. It would appear that the accurate way of dealing with this would be to credit the fund* with the total amount due for the ton mileage performed. Any interest on this amount might go towards the revenue account, miscellaneous receipts.

Contributions made on a percentage of gross receipts would not be quite accurate, unless the rates were based on the cost of carriage irrespective of the value of the articles, which is not always the case in guaranteed railways. Also gross receipts of a company often include some items that have nothing to do with the ton mileage.

The permanent way renewal, including sleepers, &c., represents one-fifth of the working expense, or one-tenth of the gross receipts, rates being for *bulk*; but of the 10 per cent. of working expense on this account, 2½ would be for labour or carriage, leaving 7½ to be contributed to the permanent way fund for materials.

Ton Mileage.

57. All that has been stated before will show the great value of the correct knowledge of the ton mileage, which alone regulates the question of railway working.

With such a correct register, the whole of the transactions of the railways of a country could be reduced to the simplest possible form, viz., payment for actual weights hauled over their own line, either for themselves or other lines; the rates on goods might be left to be recovered by the booking company and retained by it, getting in turn charged by the foreign lines for the actual weight of the vehicles and loads, whatever the loads consisted of.

With given ton mileage, train mileage could easily be ascer-

* When lines are first opened the renewals will be very small. It is highly probable that the best use of such funds would be in improvements to the lines, which would be in effect investing them at compound interest. The amounts however ought to be clearly dependent on the deterioration, and when renewals are fairly started, such improvements from revenue must gradually cease.

tained for any line, but with train mileage standards on different gauges, no analysis will be of any use in comparing results.

Some difficulty would occur in the matter of registration of ton mileage of passenger carriages including the freights, as they are continually changing, so for these vehicles, mileage should be taken culled from the guards' reports; the mileage of passengers is already kept up.

The same arrangement is therefore not required in respect of passenger-booking as for goods; the ton mileage of goods vehicles with their freight should be ascertainable from the loading invoices, which should be checked at junctions and stations where the loads are altered in any way.

Ton and vehicle mileage registration is a matter of the greatest simplicity, and seems to be a *sine quâ non* of railway practice, the value of which has only to be tested to be found to be the case.

It may be apparently difficult to see why it should be of so much importance, considering how much has been done without it; but with regard to this, it may be remarked that we are only now beginning to estimate in a general way the means for speedily producing the effect that *ought* to result from the capital invested, and it has by no means yet been demonstrated that we *might* not have done better, or that the rates have been at their lowest for the best effect, either to the companies or the country generally.

Uniformity of Stock.

58. Uniformity of carrying stock and vehicles is very much to be desired for interchange of railway stock. The advantage of this has already begun to be felt in the long journeys of passenger and troop trains. Special stock for goods is productive of very little permanent effect in economy. For instance, it is apparently advantageous to enlarge cotton wagons slightly for the same weight, since the covered wagons of that description would vary in capacity with the square of their floor area and cubage of interior space with somewhat less increase in the weight of the wagons. This is possibly the

modification of the perfectly economical form for such goods vehicles most legitimate; the increased surface of the wagons however will increase the direct wind resistance, and the same proportion of dead weight might be attained by reducing the amount of material in the wagon if that were desirable; but we have seen that there is no advantage in overweighting the wheels with heavy bodies for one thing, and in addition to this, it is a fact that almost all the stock is worked equally, owing to the return journeys either empty or only partially filled and other traffic exigencies. The mileage also of all such special stock, except such out-of-the-way things as water tanks, &c., will be found to be just the same as the average for other stock. It seems quite immaterial whether we collect more of the goods into a larger wagon and run fewer, or have less in each and run more, provided the whole weight of all the wagon stock can be reduced to a proportion with all the goods, equality being the maximum desirable.

Actual Capital Cost Proportions.

59. The proportion of capital expenditure on the G. I. P. and B. B. and C. I. Railways is given below, and some of the differences arising from the classification are explained. (See Arts. 38—43.)

G. I. P. Railway.

	December 1871.	Proportion.
Preliminary expenses	2,72,727	·38
Works	10,30,58,965	44·00
Permanent way	6,15,03,932	26·00
Stations	1,93,97,602	8·12
Electric Telegraphs	16,12,777	0·70
Rolling Stock, &c. / Machinery	3,05,89,515	13·07
Establishment	39,71,415	1·70
Engineering, Survey, &c.	1,34,77,863	5·76
Passages	4,74,746	0·20
Law	1,45,283	0·07
Rs.	23,45,04,830	100·00
Stores	1,36,04,820	5·80

B. B. and C. I. Railway.

Preliminary	28,800	0·4
Engineering	22,759	0·3
Establishment	78,741	1·2
Payments for establishment's passages.......................	54,504	0·8
Construction, plant and workshops..........................	7,06,162	10·5
Earthwork and ballast	6,35,739	9·4
Iron Bridges....................	11,81,297	17·5
Masonry do.	4,07,594	6·0
Fences	1,05,279	1·6
Roads	5,327	0·1
Level Crossings	26,696	0·4
Permanent way	14,47,407	21·5
Stations, Bungalows, &c. ...	3,64,236	5·4
Telegraphs	20,648	0·3
Rolling Stock	10,61,501	15·8
General..........................	5,85,830	8·7
Miscellaneous	6,141	0·1
Rs...	67,38,669	100·0
Stores	5,12,106	7·6

These figures appear at first sight to be somewhat discordant, but there are one or two things that can be partially explained.

The stations require sidings, which form 10 per cent. of the whole permanent way.

(*a*) The rolling stock includes machinery. The repairs of the rolling stock form 10 per cent. of the year's working, 5 per cent. of which will be for English materials, and the rest labour, &c.

Now the labour in this department, including the repairs to the machinery employed in the shops, forming the workshop expense, must, in common with all other establishments, to work economically, have a capital represented by an interest equal to the working expense.

This department may be considered a separate one turning out work annually amounting to $\frac{1}{20}$th of the whole working expense.

The whole working expense of the entire railway represents $\frac{1}{20}$th of the capital, and the workshop expense $\frac{1}{20}$th of this again; so that it seems the workshops should be represented by capital, of which the interest is $\frac{1}{400}$th of the whole expense, or $\frac{1}{20}$th of the capital.

The rolling stock forms 10 per cent. of the whole capital, so that the shops will be represented by half the capital of the rolling stock.

(*b*) But the internal working of the shops comprises in this amount—

(1). Foremen, &c.

(2). Labour, skilled or otherwise.

(3). Repairs to machinery, tools, plant.

(4). Fuel, grease, oil, water, and waste.

(5). Small stores, miscellaneous, repairs to shops and buildings.

All the other materials represented by the English stores, making up the other 5 per cent., are the result of other work done in England, for which workshops would be required, if the stock was wholly made in the Locomotive shops.

Each of these classes seems to require an equal portion of them to do the quantity of work. The foremen and labour must be proportioned to the quantity of work done in a certain time; the former will be to some extent administration charges independent of the quantity of work done in any stated time, the latter will exactly vary with the work in the time. The repairs of machines, tools, &c., will vary with the velocity of it, and quantity of work in the same time; the fuel, grease, waste, &c., will vary exactly as the quantity of work, whatever the time, and small stores will be used in proportion to the total quantity of work.

Without a classified account it would be impossible to say with certainty—but there seem to be grounds for believing,

without entering into an argument—that such an account would result in its being found that all these classes approached one another very closely, and looking at the mode of incidence of the charges, there is every probability that the amounts may be found to be equal. Under these circumstances, each would be represented by one per cent. of the working expenses, and the capital concerned would bear the same proportion.

Thus it is probable that the machinery will be 1 per cent. of the whole capital, and that the buildings, yards, sidings, stores buildings, running sheds, turn-tables, cranes, &c., will be represented by the remaining 4 per cent. of the capital. The Locomotive Superintendents and Accountants might afford much valuable information on these points.

The sidings of course, with all the permanent way involved, going to make up the capital which a contractor would have to provide to do the repairs in his own workshops, are all an addition to the expenses for the permanent way proportion if considered in it; the wear of it will be small owing to the small velocity at which the vehicles and engines are moved.

One per cent. on the whole capital is the same as 10 per cent. of the rolling stock proportion.

We find then that the proportions are—

	Rolling stock, machinery, and plant.	Permanent way.	Stations.
G. I. P.	13·07	26·00	8·12
B. B. and C. I.	15·08	21·05	5·04

In the former the rolling stock and permanent way are almost about equal in proportion to one another. In the latter out of all proportion. The B. B. and C. I. is known to have a great excess of stock for its requirements.

Deducting, however, 10 per cent. for machinery, tools, and plant in the shops and running sheds, the permanent way in the shops and yards, and an additional 10 per cent. from the permanent way for the portion of the sidings due to station construction, we find that the figures become modified, as shown below—

	Rolling Stock.	Permanent way.	Stations.
G. I. P.	13·07	26·0	8·12
Shops	— 1·30	— 2·6	......
Stations	......	— 2·6	+ 2·60
	11·77	21·1	10·72
B. B. and C. I.	15·80	21·5	5·40
Shops	— 1·58	— 2·15	......
Stations..................	......	— 2·15	+ 2·15
	14·22	17·0	7·55

The gross expenditure on the latter railway has a very large percentage for bridges, which decreases the proportion of all others. Station accommodation has not reached its full limit, and is perhaps better provided for on the G. I. P. than on the B. B. and C. I. Railway.

EFFECT OF THE CURRENT RATE OF INTEREST ON RAILWAYS.

60. If money is to be had in the market at a low rate of interest, it results possibly from accumulation of it without opportunity for investment. When such is the case, it generally means comparative idleness of the labour of the country and stagnation. That such an opportunity will be eagerly availed of for loans on good security there can be little doubt, and Government could very likely get as much money at 4 or less per cent. as they require at the present time. If capital is to be got at 4 per cent. instead of 5, it will have the effect of greatly benefiting railway or other useful operations. Cheapness of money enables development to be attained through capital in small concerns, which could actually not be thought of with money at a high rate.

We have seen that with a capital of Rs. 1,70,000 for a mile of railway, the interest at 5 per cent. and working expense should be Rs. 8,500 per annum each. The working expense is apparently independent of the rate of interest, but is it so in reality? If money is abundant and employment for it not to be found, the

same circumstance that makes the interest small must make labour cheaper, for a man will prefer half a loaf to no bread.

At 4 per cent. the interest and working expense should be Rs. 6,800, but will the same amount of work be done by the Rs. 1,70,000 invested in a railway?

The fact seems to be that, as labour will be cheaper, a line on a larger scale could be made for that same sum, *i.e.*, more labour could be employed for it. If this be the case, then it must be sufficient to spend less to do the same work.

Thus a larger scale could be adopted with less capital spent. The work required from the line will be the same to pay the interest on capital, and the working expense, as long as the rate of interest and wages remains the same, will be low.

The capital invested in the line being for actual labour performed, cannot be altered in positive value by any change in the rate of interest afterwards; but suppose the rate of money goes up and the working expenses go with it, cost of carriage will be increased accordingly, but the owner of the railway will recover 5 per cent. instead of 4 as formerly with a working expenditure corresponding.

Railways made with capital borrowed at low interest will then legitimately earn more in common with all undertakings on a general rise of profit, owing to increased activity. They will also be in a better position to maintain their superiority and exert their power, according as they have been made on a scale larger than they would have been made had money not been abnormally cheap at the time of their construction. Having the result of the constructive operations in the shape of a railway always in existence, whatever the state of the money market, the *money value* of it must fluctuate with the demand for money, the shares will go up with a general rise of prices, and general prosperity will render the higher rates charged no more burden than they were at the lower.

The State will in this respect be a gainer by the investment at the low rate of interest in common with all other proprietors, a state of things to which there appears no objection, as it is

brought about by the general prosperity *after* development has been attained.

Since a small rate at which the capital for a line was taken up would cause it a less liability for capital interest, though the working expenses would go up with the rise in rate of interest, it would still on the whole be in a position to carry cheaper than any other line not so favourably circumstanced, and it would do so with advantage if it was not already in full work; but if it was originally only just capable of carrying all the traffic, it would be a direct loss not to accept the current rate of earning; for suppose the rate of interest to go down, which it is always liable to do, the rates for railway carriage must go with it if they would carry anything at all! In fact, they must share the general expenses and profits of all other operations, and these will result in more or less profit, according to the circumstances of the time.

Means of distribution must go hand in hand with production, but the first must always keep the lead to enable the last to exist at all. If production is advancing, distribution demands more capital, which will possibly be only got at a higher rate; if production languishes, rates for distribution must be lowered, while capital may be invested at a lower rate in new districts.

In this we cannot but recognise that the proposition that interest and working expenses should be equal can apply in all operations, and with rates based on such a footing, it is impossible to see how they can be applied with better success.

All that has been said of rates has been based on the supposition that money was normally at 5 per cent. It may have been so at the time Indian construction was entered on, and till quite lately; but we have only to look at the price of Government securities daily published to see that it is now occasionally below 4. Can we, under these circumstances, expect railways to pay five?

OVERTIME.

61. There is only one course open on a fall of the rate of interest, and that is, to endeavour to see that the working

expenses fall with it, which cannot be fully the case without reduction in *number* of employés or rates of wages, or both; these cannot be effected on short notice, and press somewhat hard on the establishment. The system of *overtime* mitigates this hardship somewhat by dividing the burden between the employer and employed in this way, that while the former retains an establishment slightly above the average actual requirements of the service, at perhaps a little less pay for still less work, acceptable on account of its degree of permanency, the latter by extra exertion at busy times, according to his capacity, performs the work and receives the remuneration due to extra hands, that must have been engaged temporarily to enable the work to be done at all. To this extent overtime must be a happy expedient, but it should not ordinarily apply to single engine runs, or day's work, if they are properly arranged.

CARRIAGE OF REVENUE AND CAPITAL STORES.

62. The former are now carried free on revenue account. The stores consist of permanent way material and coal principally. Inter-departmental adjustments for the work done in different departments not being customary, nothing in the accounts will show the expenditure due to each department for carriage, so that coal is shown at a fictitious actual cost, *i.e.*, less, while more of it is shown to be used per ton mile, if only the traffic tonnage is considered.

Permanent way material being carried free is properly debitable with about 6·5 per cent. on the whole cost of the permanent way maintenance for train service.

Coal for all India carried over, say, 200 miles, would, at the *net* train cost, come to Rs. 2¼ a ton, and on 400,000 tons the probable expense on this account would be no inconsiderable item.

It might encumber the accounts to show these expenses in their proper places, but they have to be borne in mind in any analysis. Their mode of treatment in the accounts can of course not make any difference to the total financial results if no money is received for the revenue work performed.

The expense incurred is, however, a direct increase of the working cost by the net cost of the trains for doing the work.

It is true that to do this work some part of the general capital must be taken as due to it, in order that it may be done at all, and in this way it may be thought that such additions to the expenses must militate against the possibility of the line doing the whole work for the public, and consequently earning the whole guarantee, at rates calculated as proposed in former pages; but this cannot evidently be the case, because the net earnings are not only dependent on the actual income, but on the check to outgoings, and since the cost to the company is only a moiety of what it would be by any other means of transit or by the company for the public, the saving in working makes up for the occupation of the trains in the company's own apparently unremunerative work.

(*a*) But as regards *capital construction material* either for the company itself or any other company, where a money receipt should actually pass to the credit of revenue, the full rate which is chargeable to the public will apparently be no less or more than the fair one chargeable. The carrying company's working expenditure would in no way be lessened by carrying construction material on its open line at less than the public rate, while other traffic must be kept off the road to accommodate it all; but this would indirectly be contributing to the capital of the new line by deductions from current revenue, which cannot be advantageous or necessary. The carriage of materials is direct value received and a legitimate charge to capital; it would be well if there were none other less profitably incurred.

As regards the effect on a guarantee it may be looked at in this way. Admit that the actual cost to a company is only the net cost of a train or $\frac{1}{4}$ the public rate. The actual expense to the company would be recouped by a corresponding rate; but if the difference between it and the public rate for fixed charges and interest was added, while the working charge would be nothing extra beyond the labour of a book entry to show the transaction, the guaranteed interest deficit would be lessened by

so much, and the materials carried would after all not be charged with more than a fair value received.

Purchase of Railways by the State.

63. Governments have generally been shy of undertaking the construction of railways at first, and have not been unwilling to allow the first steps to be taken by private enterprise. The cheapening of carriage which inevitably follows the construction of railways even by private agency, has always been attended by good results, but it has been shown that for the maximum amount of benefit to the country and every person in it, the self-interest of the private companies ultimately imposes some burden on certain classes. As development proceeds the tendency is for benefits only procurable by the rich in the first instance to be desired by those not so well off; a cheapening of the article in demand can alone lead to the attainment of this, and in order to effect a reduction in price, the power by which articles are produced must be economised to the utmost. For such an object it is evident that the limit of price apart from the question of supply and demand, is when the value of it represents only the actual amount of labour expended in its production, allowing for the common and universal rate of profit. But private enterprise is usually not content with the ordinary rate of profit, but aims at the higher rates to be got in new and unbroken ground in operations possibly attended with much risk. There is nothing to be said against such enterprise of a *bonâ fide* character, if real work is intended and capital in hand: but this tendency leaves the well trodden paths to all the holders of capital contented to receive the ordinary rate of profit, and such might fairly be likened to the steadily growing trunk and branches, while the others represent the rapidly spreading leaves and young shoots, afterwards contributing with the trunk and branches, to the development of the whole tree.

Justice to all men, however, demands that each may be free to embark his capital in any similar business to that of his neighbour, and the prospect of large profits in the absence of protection invariably leads, in a short time, to reduction of profits;

the harvest of golden leaves is legitimately reaped where it has been judiciously sown by private enterprise; the young shoots of the tree put forth with such vigor mature into the solidity of branches, and become useful members of the whole tree, bearing fruit in due season according as the culture is diligently tended.

In all this we see that the rate of profit which suits private enterprise best at first in new fields, and confers advantages on the people of the opened up localities, must suit the country at large better ultimately when the rates by competition have been forced down to the ordinary rate of profit.

The capital will then most possibly change hands; the first investors being anxious for higher rates will transfer their money to other schemes, and the lines will pass into the hands of people content with the ordinary rate of profit.

The action of competition in reduction of profit to the ordinary rate is so certain and universal that it might be with confidence predicted that where a higher rate existed, there was not perfect freedom from protection.

Now this is just what occurs in practice, and enables some companies to pay 6 or 7 per cent., while others, owing to the injudicious nature of the works or heavy burdens borne on the capital account—though they may be taxing trade on what they do earn—are only returning 1 or 2 per cent. Protection therefore has occurred in various ways not the least being the heavy legal and Parliamentary expense inseparable at present from the railway system, which must deter investors from undertaking competing schemes. Had protection been absent, and a control resulting in the avoidance of injudicious construction been exercised, England would no doubt have had twice the mileage open with better results, and a universal rate of dividend being earned equal to the current rate of profit.

When such a state of things occurs, who are the persons for whom an investment in the stock is most suitable?—surely those who are content with the ordinary rate of profit,—and who should be so content as the State?

It seems clear then, that whether the attainment of the current rate of profit is the result of complete development assisted by unrestricted competition, or whether it is the result of unbounded confidence which enables money to be borrowed at that rate, before construction is commenced, the State, *i.e.*, the country at large, must be the most interested holder of the stock generally, for by its agency the greatest development in the country can be attained at least cost, enabling it thus to support the private enterprise of the nation in its endeavours to keep the leading position in supplying the home markets and the markets of the world with interchangeable commodities.

It is interesting to note how excesses, which generally are corrected by deficiencies somewhere or another, influence the case of English railways as regards the capital and interest earned.

Mr. William Chambers, at page 85 of his book, shows that notwithstanding the enormous capital and high interest in some lines the average profit in 1864 was only 4·16 per cent., and remarks—" acknowledgedly an insufficient return on outlay, but the inadequacy of the amount is due in a great degree to the waste of capital on parliamentary contests, and also on the construction of lines to supersede or rival others already in operation;" the reasons pointed out in Art. 47*f* may be added.

It seems that a country represented by its Government is at liberty to adopt any method it chooses for developing its resources. But its Government, though professedly the essence of the nation itself, may be influenced by the interest of classes, and it seems hardly possible to treat a question of purchase or construction of a railway system by the State apart from the interests concerned.

It appears that on the part of the sellers, as long as only the ordinary rate of earning is being received, that it will become a matter of indifference to the shareholders whether the State takes charge or not; if less is being earned, they will be anxious to realise, whoever may be the purchaser, and if more they will perhaps prefer to retain their stock. Should the purchase be

decided on, however, it appears that the whole capital wanted would not exceed what could be got at 4·16, or whatever per cent. the rate earned might be, if clauses in the Acts exist by which the stock can be taken at an average of the market price for some time previously. No hardship would result to any one except perhaps the stock-holders of inferior lines who might be living in hope of their prospects brightening.

But as regards the purchasers, *i.e.*, the *nation*, the people will be affected in different ways. On the one hand, all the money which has usually been travelling into the purses of persons mixed up with Parliamentary and other unproductive charges will be diverted, such persons will oppose the transfer to the State ; on the other hand, the immense incubus of this expense being removed, impetus will be given to expenditure on *bonâ fide* construction. All such persons as are interested in the construction will be in favour of the transfer.

All persons engaged in floating new undertakings, amongst whom will be some mere speculators, will be against the transfer. All persons preferring the ordinary and sure rate of profit will be in favour of the transfer.

But after all, those in opposition referred to in the above, form a very small portion of the community, though perhaps one largely represented in the Councils of the nation. There is that other element of the State, the *working power*, representing the present effort—the offspring and equivalent of former labour—just as capital is the excess of previous labour stored up over that consumed. What does this element say—why, it is easy to imagine, it simply desires to enjoy the common benefits of its labour, without working to support costly institutions from which no advantage arises to it. That it is unable to travel and reap many blessings owing to the tax inevitably proceeding from the inclusion of unproductive capital charges in the railways of the country. It may say, that the Parliament, which should be its protection in this matter, is apparently the direct means of the oppression complained of, if these enormous expenses are inseparable from its action; and that the time has come when a system

which has resulted in this state of things—though it may not have been without advantage in tending to bring the element to the power it now is, in the earlier stages of development of the country—now requires for further development to be attained that these burdens should be removed; that Parliament should facilitate the construction of railways by every means in their power, and make the benefits apply to all equally.

That this may be done with little or no risk is perfectly certain. The immediate effect would doubtless be the expansion of the railways all over the country, the doubling of over-worked lines, cheapening of carriage, absence of accidents, improvement of property, uniformity of system, and increase of comfort to the poorer classes.

Concluding Remarks.

64. Much of the obscurity in which questions of railway economy as regards the working is involved, has no doubt resulted from the circumstances surrounding enterprises of a private nature, which have tended to the suppression of useful information through a mistaken notion that the value of the shares might be affected by the truth being known, and so on; but as far as can be seen by an impartial eye, the very reverse appears more likely to be the case, and that with every confidence that things were perfectly open and accurately known, the investor would be much more ready with his money at a lower rate of interest.

For as many individuals made happy by the præmia received on shares fictitiously high in value, there must be as many others rendered miserable by the purchase. For as many persons embarking their hard earnings in useful works likely to return the ordinary rate of profit, there may be many happy homes, but can on that account be no desolate ones to mar the other side of the picture.

A cause also of comparative obscurity in the operations of works is often the reluctance of departments to incur the small expenditure for a few clerks necessary to compile statistics.

An error in the general direction from the fountain head makes a wide difference when multiplied by the action of the many parts through which the final effect is attained, and we all know that the mariner's compass if only a point out may lead the ship in course of time miles out of her reckoning. An error in first design can never be remedied by any patching afterwards, and it is useless to try to hide defects even under any amount of ornamentation. We have only to look to the results arising from the want of correct information, to see that we are bound to take every step which shall place us in possession of the real facts.

If the substance of the foregoing inquiry be ascertained to represent the true state of the question, there are many points that will strike thoughtful minds as being directly opposed to our present line of action. For instance, all our endeavours appear to be applied to perpetuate a system of over-worked lines by cramping their first design and then applying the remedies of excessive loads, without a single advantage in the way of increased dividend, while many disadvantages in regard to speed and comfort, to say nothing of the loss of power in a military point of view, are inevitably inseparable from such a course. It is tolerably certain that a donkey will perform $\frac{1}{5}$th the work of a horse; but are there many men who having enough work for a horse will prefer to employ five donkeys? In truth, there do not seem to be wanting persons who would so prefer, and even some ready to undertake the work of a horse with a single donkey.

It is highly improbable that the large deficit accounted by some as such a burden, is likely to be much lessened by any other smaller scale being adopted for the lines, and that with extraordinary charges against revenue, such as have been illustrated in this paper, much of the deficit will be due to causes which would affect all gauges equally.

The railways are at present inactive because trade is dull, and there is perhaps no more accurate trade barometer than the railway receipts of a country. It is excessively likely that as

long as this continues so long will railways be returning a small dividend; it will be well not to attach such an effect to a different cause, such as over-estimation of railway capacity, &c., till we know what the requirements are likely to become ultimately, and it will be well to note when we know this, that they can probably only be met with greatest advantage to all concerned by an expenditure of capital in exact proportion to the work to be done.

Neither the American or English lines are earning more than average dividends, though they are charging very high rates and are doubly over-worked: nothing would be gained by an introduction of such systems where money can be had cheaply.

The author must not conclude without expressing his acknowledgments to the many gentlemen associated with him in the engineering line, some of whom will, it is hoped, recognise the influence their ideas may have had in any of the conclusions arrived at without regarding them as misapplied.

But special thanks are due to Mr. T. G. Newnham, C.E., Chief Engineer of the Sind Railway, for the cordial and disinterested way in which he afforded the author every information in his power regarding the working of the Engineer and Locomotive Departments in his charge.

Three years ago it was the author's good fortune to be sent, on first appointment to the Railway Department, to act as the Deputy Consulting Engineer to Government for Railways in Sind, and one of the first things he was called on to do was to bring the Company to book for an excessive train mileage of some period, and to suggest heavier trains being run. These instructions being forwarded—let us hope with all due humility—for information and guidance, elicited a reply, emanating from the talented Chief, to the effect that the trains could of course be run heavier if desired, but that as they were then running at their economical maximum, no alteration could effect a sav-

ing! Here were truths! Could it be possible to overload a train any more than a Bombay bullock hackery! It had seemed conclusive that the longer the train was the better.

On pursuing the inquiry, however, the Chief brought out piles of tables and diagrams constructed in his leisure hours, clearly demonstrating the whole thing, and showing, it is believed, that the economical load for that line was 35 vehicles at 11 miles an hour.

It appeared then that if there were limits to trains, there must be limits to everything else; and bearing in mind that the limit of the reader's patience may have been nearly reached, it will be sufficient to say that after many struggles and much consideration of sadly conflicting evidence, the limits of the principal proportions of working expenses, and their effect on the policy of railways, have been determined as set forth; but the author disclaims any intention of offering them for final acceptance, or of identifying himself with them longer than they will stand the test of further inquiry without necessitating modification.

APPENDIX.

DATA FOR CALCU

JANUARY,

WEIGHT OF ENGINES AND TENDERS,

—	Weight of Engines.	Tenders	Water.	Fuel.
G. I. P. RAILWAY.				
Goods	30 tons.	10*	6·7	5·0
Passengers	27 „	10*	5·8	3·5
B. B. AND C. I. RY.				
Goods....................	35·6 „	7·0	6·02	3·0
Passengers	31·5 „	10·0	8·0	3·0
SIND RAILWAY.				
Goods	28·0 „	13	8	3
Passengers	26·4 „	12	5·8	3

* Assumed.

Total weight to be taken, reckoning only 0·6 of the fuel and water for the whole distance. The totals will thus be:—

—	G. I. P. Railway.	B. B. and C. I. Railway	Sind Railway.
	Tons.	Tons.	Tons.
Goods	45·8	47·1	46·5
Passengers.........	41·6	46·5	42·8

DESCRIPTION OF VEHICLES.
GOODS.
High-sided Wagons......
Low-sided, 20 feet, with raised sides ...
Do. 16 feet, wood.
Do. 12 feet, iron..
Cotton Wagons, covered...
Do. do. 20 feet, iron, flat...
Do. do. do. low-sided...
Covered Goods, wooden.
Do. do. iron-framed.
Timber Trucks............
Rail do. ....
Carriage do. ....
Powder Vans ....
PASSENGERS.
Saloon ....
1st Class ....
Composite..................
2nd Class ....
3rd do. ....
4th do. ....
Carriage Trucks ....
Horse Boxes...... ....
Road Vans ....
Brake Vans, Passenger..
Do. Goods ......

Proportion of cost of Water, Grease, Oil, &c., to the whole cost of Water, Grease, Oil, and Fuel, and proportion of Grease, Water, and Oil to cost of Fuel in the Revenue Account.

	Proportion of Grease, Water, and Oil to whole cost.	*Proportion of Grease, Water, and Oil to cost of Fuel.*
B. B. & C. I.........	16 per cent	20
Sind..................	20	25
G. I. P...............	21	25
Madras...............	28	40
Great Southern ...	12	13

LATING RATES, &c.
1872.
CARRIAGES AND WAGONS.

Great Indian Peninsula Railway.		Bombay, Baroda, and Central India Railway.		Sind Railway.	
Weight of Vehicles.	Weight made to carry.	Weight of Vehicles.	Weight made to carr y.	Weight of Vehicles.	Weight made to carry.
Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
4·80	6	5·05	8	4·85	6
5·35	7	......	......	......	......
......	......	5·30	8	......	......
......	......	4·25	6	......	......
6·50	7	6·00	8	4·35	6
......	......	5·95	8	......	......
......	......	5·21	8	......	......
5·70	7	5·85	8	5·41	6
......	......	......	......	6·20	6
......	......	4·55	5	4·35	6
......	......	......	......	4·30	6
......	......	4·60	......	4·30	6
......	......	6·95	......	7·70	6
	No. of Passengers.		No. of Passengers.		
7·35	12	7·95	17	7·5	21
6·25	20	7·95	24	6·9	26
8·65	24	7·70	36	7·23	32
8·13	30	7·80	40	7·00	32
5·10	40	6·90	60	6·31	50
4·70	40	None.	......	......	......
8·65	1 carriage.	4·65	1 carriage.	4·4	1 carriage.
5·15	3 horses.	8·65	6 horses.	6·32	3 horses.
		6·60	3 do.		
5·15	5 tons.	5·85	......	Brakes used.	......
7·25	......	8·00	......	7·23	......
6·55	......	6·20	.....	8·27	......

NOTE—*Great Indian Peninsula Railway.*—The 19 and 20 feet low-sided wagons with raised sides, so far as the body of the wagon, itself is concerned, will carry double its own weight, but the present axles and springs would be too light.

Bombay, Baroda, and Central India Railway.—The large size goods vehicles are constructed to carry eight tons, but from the liability to heated axles with the present axle boxes, this load is not usually permitted, but is limited to seven tons.

		Tons	Cwt.	
20 feet covered wagons will contain	18 small bales =	3	10	half-pressed cotton.
	or 14 large do. =	3	13	do.
20 feet open do.	21 small do. =	4	1	do.
	or 17 large do. =	4	8	do.
Covered goods wagons are used in busy season to carry cotton, but will only contain....................		2	6	do.

All classes of large wagons will carry a full load of full-pressed cotton, that is 46 bales, 4′ × 2′ × 1½′, at 3½ cwts. per bale, 8 tons 1 cwt.

Average Pay, exclusive of Overtime, of Guards, Drivers, and Firemen.

	Great Indian Peninsula Railway.			Bombay, Baroda, and Central India Railway.		
	No.	Average pay monthly.	Night Allowance.	No.	Average pay monthly.	Night Allowance.
		Rs.			Rs.	
Guards ...	313	100	10 Annas.	36	75	10 Annas.
Drivers ...	222	155	1 Rupee.	38	160	8 Annas.
Firemen ...	499	28½	3 Annas.	61	23	3 Annas.

The numbers employed of course vary; those given are for the month from which the average has been taken.

Number of hours worked per day.

Engine Drivers........................... 7 hours.
Guards .... 10 „

From the average number of hours worked per day deduct—

Bombay, Baroda, and Central India Railway,—1 hour for bringing Engines into and out of shed.

Great Indian Peninsula Railway,—1½ hour.

Average Full Loads of Vehicles per Train.

——	Passengers.	Goods.
Great Indian Peninsula Railway	13	30 Loaded.
Bombay, Baroda, and Central India Railway...	20	40 Loaded.
Sind Railway	15	35 Loaded.

Two full, equal to three empty goods vehicles.

Average speed of Trains, including stoppages.

Passenger	21	Bombay, Baroda, & Central India Railway.
Mixed	14	
Goods	11	
Mail	23	Great Indian Peninsula Railway.
Ordinary	17	
Mixed	11	
Goods	10	

For charges over portions including the ghauts, the rule is now 32 miles extra for the Bhore Ghaut, and 20 for the Thull Ghaut.

Balance of traffic about 30 per cent. towards Bombay or the coast.

Equivalent of English Coal.

	Per ton mile.	Cost per lb.
Allahabad-Cawnpoor	0·121 lbs.*	Pies.
Baroda Railway	0·140	1·90 „
Sind Railway	0·180	2·36 „
Great Indian Peninsula Railway	0·200	1·90 „
†Madras Railway	0·209	1·25 „
Great Southern of India	0·211	1·70 „

EXPERIMENTS ON RUNNING TRAINS.

B. B. and C. I. Railway.

Cowper Hartley .... ·162 lbs. per ton mile.
Crown Patent Fuel .... ·132 „ „

Madras Railway.

1 Ton English Coal = ... 3·39 tons wood.
1 „ Coke = ... 3·31 „ „
1 „ Crown Patent Fuel = ... 3·99 „ „

General Traffic Stores, including Lights, Clothing, Printing, Stationery, and Tickets.

	Per Train Mile.
B. B. & C. I. Railway	32 Pies.
Sind	36 „
G. I. P.	17 „
Madras	12 „
Great Southern	10 „

* Experiment with Native coal reduced to equivalent of English.

† Burns a great deal of wood. Power of coal reckoned at 2½ times that of wood.

Proportion of the Expenses in any Train.

Train Staff	1
Station Staff and Expenses	1
	2
Repairs of Rolling Stock and Rails	2
	4
Fuel, Water, Grease, Oil, and Waste	4
Total train expense	8
Administration, Maintenance, Miscellaneous, Stores, and Fixed charges	8
Total cost	16
Net earning or interest on Capital	16
Total rate	32

N.B.—For a line costing Rs. 1,70,000 a mile, the train staff charge per hour must be 1·91 Rs.—(See next page, and Art. 44 *a.*)

Average Run per Trip.

Passengers	154 Miles.
Goods	71 „

Rule for finding the cost of hauling a ton one mile.

Five times the cost of a pound of fuel divided by the number of tons hauled a mile by a pound will give the gross cost of a ton over a mile ....(I).

The ordinary rates including interest would be double the above...(II).

For the cost of a ton of freight with or without interest.

Multiply the result of the last operation by the proportion of the whole load to the freight.

Example:—Cost of fuel 2 pies per lb.; No. of tons per lb. 7; proportion of whole load per ton of freight 3:

$\frac{5 \times 2}{7} = 1{\cdot}43$ pies per ton gross. $1{\cdot}43 \times 3 = 4{\cdot}29$, cost per ton of freight...(I).

The rate $= 4{\cdot}29 \times 2 = 8{\cdot}58$ pies........................(II).

Deduction of Train Staff Charges per hour.

Between Ahmedabad and Bombay. (308 *Miles.*)

Goods, rate of running 11 miles, giving 28 hours in 4 trips.

Passenger, rate of running 21 miles, giving 14·7 hours in 2 trips.

	Goods.	Passenger.
DRIVING.		
No. of Hours running	7·00	7·36
Shed and light running	1·5	1·50
	8·5	8·86
No. of Trips	4	2
	34 at R. 1 = 34·0	17·72
Night Allowance	$\frac{8 \text{ as.}}{2 \times 16} \times 4$ trips = 1·0	·50
	35·0	18·22 at R. 1 = 18·22
		18·22
GUARDS	4 at 2½ = 10·	2 at 2½ = 5·
Night Allowance	$\frac{10 \times 4}{2 \times 16}$ = 1·25	1 at ·62 = ·62
	11·25	5·62
FIREMEN	8 at $\frac{23}{30}$ = 6·13	4 at $\frac{23}{30}$ = 3·06
Night Allowance	$\frac{3 \times 8}{2 \times 16}$ = ·75	2 at ·19 ·38
	6·88	3·44
Total Train Staff	Rs. 52·88	Rs. 27·28
	1·91 Rs. an hour.	1·91 Rs. an hour.

Fuel per Ton Mile.

—	Dec. 1870.		June 1871.		Dec. 1871.		June 1872.		Dec. 1872.		
	lbs.	pies	lbs.	pies	lbs.	pies	lbs.	pies	lbs.	pies	
Great Southern of India	·199	·348	·215*	·298	·210*	·316	191†	·233	...	...	Gradient over 300 only 1-7th of open mileage, coal Rs. 21·5 per ton.
Madras	·427‡	·322	·418‡	·310	·374‡	·300	·402‡	·277	...	..	Steep gradients common; fuel 8·6 Rs. per ton.
G. I. P.	...	...	·200	·346	·200	·410	·176	·338	·192	·354	Gradients of 1-200 frequent; 2 ghauts; coal 25 Rs. a ton.
B. B. and C. I. ...	·190	·336	·143	·295	·194	·406	·176	·338	·195	·370	Level line, coal 25 Rs.
E. I. Jubulpore .	...	...	...	...	·255	·460	·204	·320	...	...	Gradients 1-200 frequent; coal 20 Rs. a ton.
,, Main Line.	...	...	...	...	·173	·086§	·181	·073§	...	...	Level line; coal 5·0 Rs. a ton.
East Bengal......	·213	·204	·264	·244	·244	·208	·236	·192	...	...	Level line; coal 10 Rs. a ton.
Oude, Rohilkund	...	...	...	...	...	...	·481‖	·336	·495‖	·266	Level line; fuel 6·3 Rs. a ton.
Punjab, Delhi ...	...	...	...	...	·520‡	·444	·573‡	·480	...	...	Generally level; fuel 9·0 Rs. a ton.
Sind	·173	·500	·172	·470	·202*	·332	·285‡	·202	...	...	Gradients 1-200 frequent; coal 32 Rs. a ton.

* Coal, patent fuel and wood.

† Half patent fuel; patent fuel slightly dearer than coal.

‡ Wood.

§ Coal apparently 5·2 Rs. a ton; not reliable. The Jubulpore line appears too high and E. I. main line too low in quantity and price.

‖ Coal and wood.

Remarks:—The registers of ton mileage are not at all perfect generally. They probably do not include more than traffic mileage at the most. There is a large quantity of work done on Revenue account free, regarding which nothing is known. The table above given is therefore approximate only.

Explanation of the Diagram.

(See Arts. 24 (*g*) and 27.)

O X and O Y are the axes at right angles to one another. Lines of unlimited length are drawn parallel to O X at distances apart corresponding to the proportions of train expenditure. The circle being described on the fuel, grease, oil, and water line and the circumscribed square completed, a line passing through O, the centre of the circle, may be taken to revolve about that point, and if of unlimited length, it will cut the train charge lines somewhere in every position except one, viz., when it coincides with the fuel, &c., line.

Suppose it first to occupy the position A B, the amount of the charges may then be measured on each line by the sides of the triangles marked T S R, F G O W, FIXED.

Suppose it next to take the position *a b*, the charges will then be represented by *t s r*, &c. Again, if it occupy the position of line **A B**, the charges will be represented by T S R, &c.

These charges will always be in the same proportion, but will vary in amount with different velocities.

When the velocity is very great, the charge per mile for train staff will be very small, and *vice versâ*, and the whole charge for trains will be small or large in proportion.

The nearer approach to the line O X that A B makes, the higher the velocity is represented, and when coincidence takes place, the velocity may be considered infinite when there would be no charge and equally nothing for the train; in fact, there would be no train at all since fuel, &c., would also in that case become nothing.

On the other hand, the more the line A B recedes from O X the larger the train staff becomes, thus representing slower velocity; and when the limit is reached the line will coincide with O Y, in which case the velocity will be infinitely slow, which will ultimately mean no velocity at all, and consequently no work done.

Both these extreme limits are evidently unapproachable if there is a train at all run at any velocity.

The expense of the trains must be as the velocity in order that the same cost per ton mile may result. The weight of trains increases as the velocity diminishes, and *vice versâ*. The fuel, grease, water, and oil item being thus the pivot round which the expense of all trains

revolves, and it being possible to utilise it with different loads and speeds, there must be some load which will admit of greatest speed.

Then since the revolution of the line A B round O starting from the fuel, &c., line, means at **A** large load with small velocity, medium load and medium velocity at A, and small load with great velocity at *a*, ending finally at X in no load with infinite velocity, it will be evident that the largest load with largest velocity must occupy the position of the line A B.

Next as regards the number of trains in which any fixed quantity of traffic is taken.

The sides of the shaded triangles parallel to O Y are taken to represent the charge at different velocities. In proportion as the velocities increase, the loads of trains decrease, and *vice versâ*; but as the loads decrease, the number of trains for the same quantity of traffic must increase, and the reverse.

If the sides of the shaded triangles represent the charges for different trains, the number of them required for a fixed quantity of traffic may be represented by the sides parallel to O X.

Then, when the velocity is infinitely great as at X, the number of trains having increased in inverse proportion to the charges will be infinitely great, at *a* there will be a large number of trains at great velocity, at A a medium number at medium velocity, at **A** a small number of them at a slow speed, and the limit will be reached at Z, when there would be one train at no speed at all.

The limits can evidently not be reached if there is both load in one case or speed in the other.

The smallest number of trains of greatest velocity and the smallest number of trains with greatest weight must occur in the position of the line A B, and when consequently all the charges varying with the *velocity* equal those varying with the *number* of the trains, for then alone will the two sides of the triangles be equal.

Thus it will be evident that as regards the *duty* of the railway it might be done by collecting all the engine-power and station and train staff, into one train loaded with the whole of the traffic, and requiring the total gross charge for fuel and repairs, and the net charge for the train would be no more than if it was made up of several travelling separately at the same velocity.

Such a train might then travel at any velocity; the *cost* would remain the same, for fuel, grease, oil, and water are independent of the

velocity for total duty, while repairs would increase as the velocity, and train and station staff would diminish in like ratio.

But the greatest velocity with least expenditure on *both repairs and staff* would be when the two were equal.

There is consequently a particular velocity for any fixed quantity of traffic. But velocity can only be produced by expenditure of fuel in proportion to the velocity desired for a given weight.

A proportion of the fuel for different quantities of traffic is therefore required to produce velocity, while the other proportion is required to move loads in proportion to the traffic.

For any given load at any velocity the load and velocity are in inverse proportion to one another, thus the quantity of fuel which will develop most work for both elements in the shortest time, is that in which the velocity and load are both greatest, and this can only be when half the fuel consumption is due to velocity and half to load. If the sides of triangles parallel to O Y are now taken to represent weight, and those parallel to O X velocities, it may be shown as before that the greatest effect of the fuel will be when the line revolving about O occupies the position A B, velocity and weight charges corresponding to the equal sides of the triangles being then equal.

The other charges being represented in all cases by similar proportional triangles, must all be most usefully incurred when the line A B represents their amount, for then they will all be maxima.